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Experimental Investigation of the Transition of a Signal to Chaos in a Network of Nonlinear Amplifiers*

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The transition to chaos of a signal in a network of nonlinear amplifiers was investigated theoretically in [1, 2]. It was shown that the principal factor, determining this process, is secondary instability of the conversion of the periodic signal. The nonlinear development of this instability leads to a "filling" of the spectrum and to the formation of a chaotic signal at the output. This paper presents the results of an experimental investigation of the transition to chaos of a signal in a network of amplifiers.

The experiment was conducted with a network, one section of which consisted of a series-connected nonlinear amplifier and low-frequency filter. A multiplication circuit was used in the amplifier; therefore, the signal u_+ at the output was expressed in terms of the signal u_- at the input in the following manner:

$$u_+ = \lambda - a u_-^2 \qquad (1)$$

where $a \simeq 2.0\ \mathrm{V}^{-1}$ and the parameter λ could vary within the interval from 0 to 1V. The linear filter had the transfer characteristic $L(f) = (1 + i f f_0^{-1})^{-1}$, where $f_0 \simeq 3$ kHz. Thus, the experimentally realized system matched in accuracy the one investigated theoretically in [2].

As shown in [1, 2], if a periodic signal is fed to the input of a network of amplifiers, the signal remains, strictly speaking, periodic after any number of sections. However, such a multiple transformation of a periodic signal can be unstable with respect to the excitation of other frequency components. In the experiment, this instability should appear (even if no special perturbations are supplied) in the form of an increase in fluctuations. Figure 1 shows the results of an experiment on transforming a periodic signal for two values of the parameter λ. For $\lambda = 0.5$, Eq. (1), considered as a transformation of a signal into itself, has a stable cycle of period 2. Correspondingly, there is a stable transformation regime of the input periodic signal. For $\lambda = 0.95$, Eq. (1) leads to a chaotic (in terms of n, the number of the section) signal variation. Correspondingly, as shown in [2], the transformation regime of the period signal is unstable; this is also seen from Fig. 1. The periodic component becomes essentially

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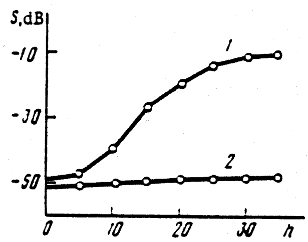

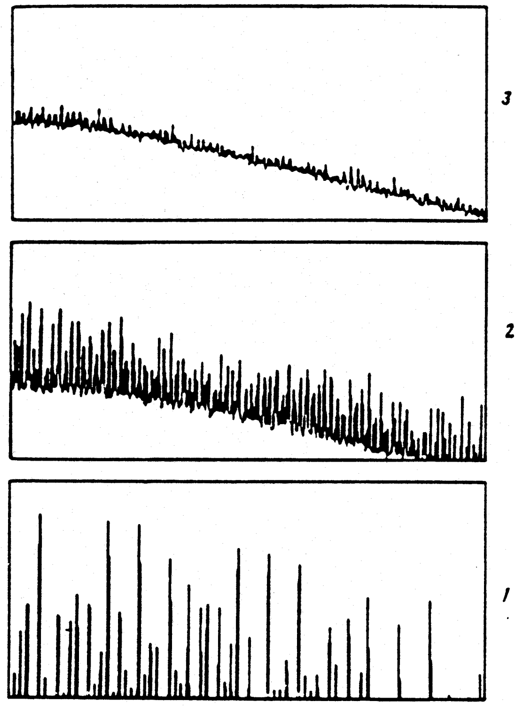

Fig. 1   Fig. 2

Fig. 1. Evolution of fluctuation level S along network; curves 1 and 2 to $\lambda = 0.95$ and 0.5.

Fig. 2. Evolution of spectrum P of a quasiperiodic signal along network; $n = 10$ (1), 20 (2), 30 (3).

indistinguishable from the background of fluctuations after the 35th section; this agrees with the estimate given in [2].

In the secondary instability regime ($\lambda \gtrsim 0.95$) we investigated the transformation of a quasiperiodic signal. A sume of two sinusoidal signals with frequencies $f_1 = 177.14$ Hz and $f_2 = 286.57$ Hz was fed to the input. These frequencies were chosen from the condition of best approximation of the ratio f_1/f_2 to the irrational number $(\sqrt{5} - 1)/2$ (the so-called "golden section"). According to [2], with the passage of such a signal all possible combination frequencies $k \cdot f_1 + m \cdot f_2$ appear, as a result of which the spectrum becomes essentially continuous. This was confirmed by the results of the experiment, shown in Fig. 2. The appearance of the combination frequencies was accompanied by a growth of the continuous spectrum, leading to a transition of the signal to chaos. For $n > 30$ the statistical properties of the signal (spectrum and distribution function) were essentially independent of n.

In conclusion, let us point out that the transition of a signal to chaos in a network of nonlinear amplifiers is completely analogous to the spatial development of chaos in a nonlinear medium with a convective instability [3, 4].

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