Polatsk

B.I.Stepanov Institute of Physics
Academy of Sciences of Belarus
State University of Belarus
Research & Industrial Centre MIGMA

FEBRUARY 15–17, 1993, Polatsk, Belarus

Editors
V.I.Kuvshinov and D.W.Serow

Proceedings of Second Annual Seminar

NONLINEAR PHENOMENA IN COMPLEX SYSTEMS

Fractals, Chaos, Attractors, Bifurcations, Phase Transition, Self-organization

Saint-Petersburg

Some Distinctions of the Behaviour of Nonlinear Anharmonic Oscillator Structures in Hyperconductors under High Magnetic Fields

V.R.Sobol, O.N.Mazurenko, A.V.Petrov

† : *Institute of Physics of Solids and Semiconductors*
Academy of sciences of Belarus,
P.Brovky St., 17, 220072, Minsk, Belarus

This report is devoted to the study of behaviour distinctions of the series RL diode circuit that was a non - independent dynamic system with time-dependent right part represented in the following form:

$$X = f(X,t); \quad X(t_0) = X_0.$$

In this case vector field describing the system condition in moment of time t, contains one or two components. In [1] is shown that the RL circuit with diode may have very complicated asymptotic behaviour and also it may have the bifurcational doubling at certain values of harmonical source voltage V. Thus in ordinary case for every value of V there are reproduced the values of diode voltage $v(t_0 + nt)$ with $n = N, N+1, \ldots$, where T - is a source voltage period, t_0 - time constant, which value lies between 0 and T, and N - value large enough, so that transition part of the change in time tends to zero at NT moment of time. Normal behaviour of the system takes place when all the values of $v(t_0+NT)$ are the same in magnitude and the voltage $V(t)$ is asymptotically periodic with period T. The appearance of bifurcation means that at some value of V the line of $v(t_0 + Nt)$ points occasionally follow two distinct paths (branches), so that the voltage $v(t_0 + Nt)$ oscillates between two values and the voltage is asymptotically periodic with the period $2T$. At these source voltage V values the magnitudes of voltages and currents in the circuit tend to subharmonic 1/2.

In the modelling of the circuit functioning it is necessary to choose the adequate model of diode, which is the source of system nonlinearity. For this purpose most frequently is used nonlinear resistor with exponential characteristic. In [2] is shown that resulting circuit in this case is normal at any amplitude of V. In other words, with the help of the likewise diode model it cannot be explained the appearance of bifurcational voltage period doubling on the diode.

Complicated dynamic process can't arise even in the case when capacitor with linear capacitance is switched in parallel to the diode. Substancial feature of subharmonics generation and exhibition of chaotic behaviour is the existence of diode nonlinear transition capacitance switched in parallel to the nonlinear diode.

In [3] are shown the results of computer modelling of the circuit in which the diode model consisting of resistor with exponential characteristic and capacitor was used which had fractional - power characteristic with cut-off diode and exponential one with opened diode.

For the simplification of calculations, in [4] there was made a simplification of diode model, in which a nonlinear resistor with piecewise-linear characteristic and a capacitor with nonlinear capacitance were used. The both characteristics had only two linear branches with the same critical points which correspond to the cut-off and the conducting stations of diode. Resulting bifurcation diagram is similar with the previous one, which shows that qualitative aspects of changes in time don't depend on the concrete form of circuit elements characteristics.

In [5] resistor was excluded from the diode model so that the circuit used contained only nonlinear element - capacitor with nonlinear characteristic. This evidences of structural stability of these phenomena.

In present case there were studied time dependences of voltages on different elements of series RL diode circuit at different levels of system excitation. In so doing there were plotted phase portraits of the following dependences: diode voltage - current; source voltage - current; source voltage - diode voltage. Frequency range included not only circuit ch racteristic frequencies but more distant values as well.

On the series of figures there are represented the depender es of system phase portraits, constructed in "voltage - current" coordinates of the diode at several characteristic frequencies of system excitation. Thus, the attention is attracted by the fact that the phase portraits shape is determined by the source voltage value and undergoes substantial changes of not only qualitative nature but also of quantitative one. By doing it the change degree of this portrait shape is determined by the closeness to the characteristic frequency. On the dependencies of signal portraits upon time, being represented in the form of ordinary oscillogrammes, it is reflected the dynamics of oscillation processes change in the circuit at the source voltage change. Characteristically, nonlinear effects in the circuit begin not at once, i.e. not from zero level of the voltage, but at some finite amplitude. This is obviously concerned with the threshold character of the diode functioning at forward bias voltage. Thus, under the reverse bias $p-n$ junction resistance is several MOhms, but under the forward bias the diode "switches" on the conductivity process, displaying resistance to the direct current of several Ohms at several one-hundredth parts of Volt. At smaller values of forward bias voltage the diode displays zero conductivity.

There arises a question of the reason of circuit nonlinearity and the bifurcations appearance. What is implied is the reason of the diode nonlinearity, that leads to the observed effects. Obviously, distinctions of resistive properties cannot lead to such a complicated behaviour. Here, as before, the main role is played by nonlinear diode capacity. Bifurcations, if appear, are hard to observe in a time scale, because of a new periodicity type a better resolution is needed to see. It seems, that the small regions of the phase portraits, being shifted with the change of source voltage, are not bifurcations by the reason that on the oscillogramme in that case there might have been characteristic nonlinear element voltage changes with the period of $2T$, $4T$ and so on.

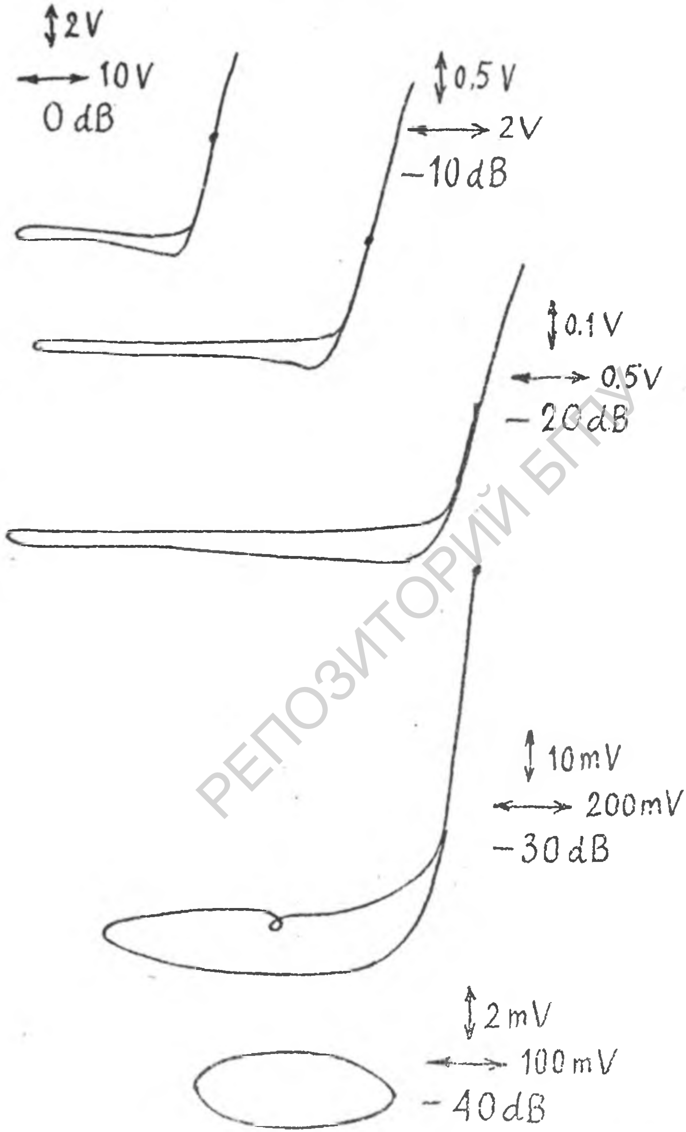

Fig.1. The phase portraits of "diode voltage V — diode current" dependence at different excitation levels for the frequency 10000 Hz.

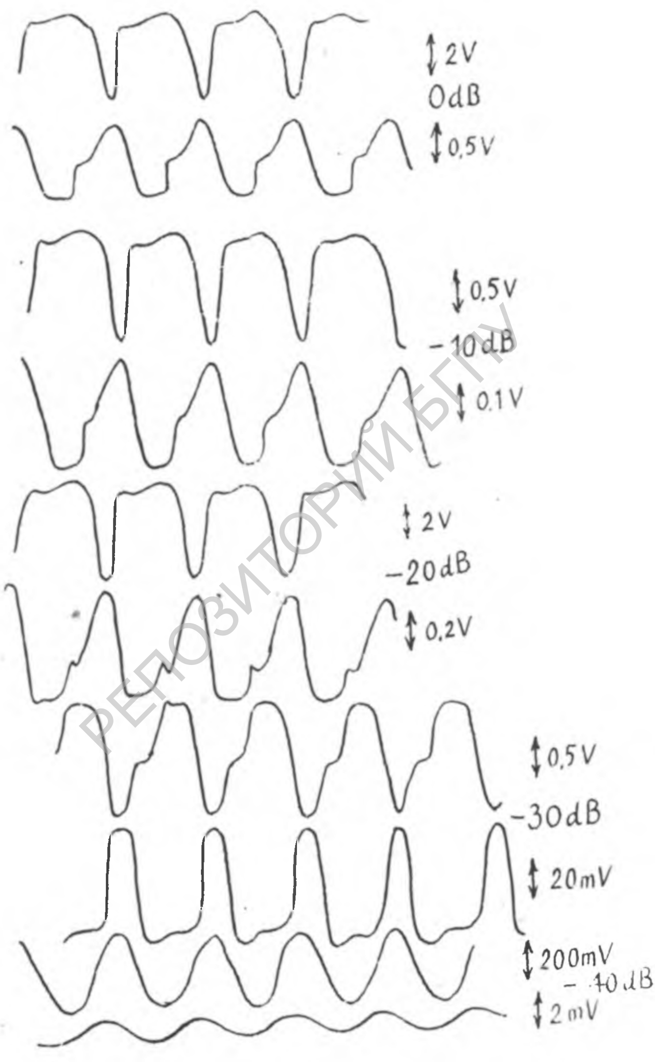

Fig.2. The oscillogrammes of diode voltages V and diode current for the frequency $10000 Hz$ at different excitation levels.

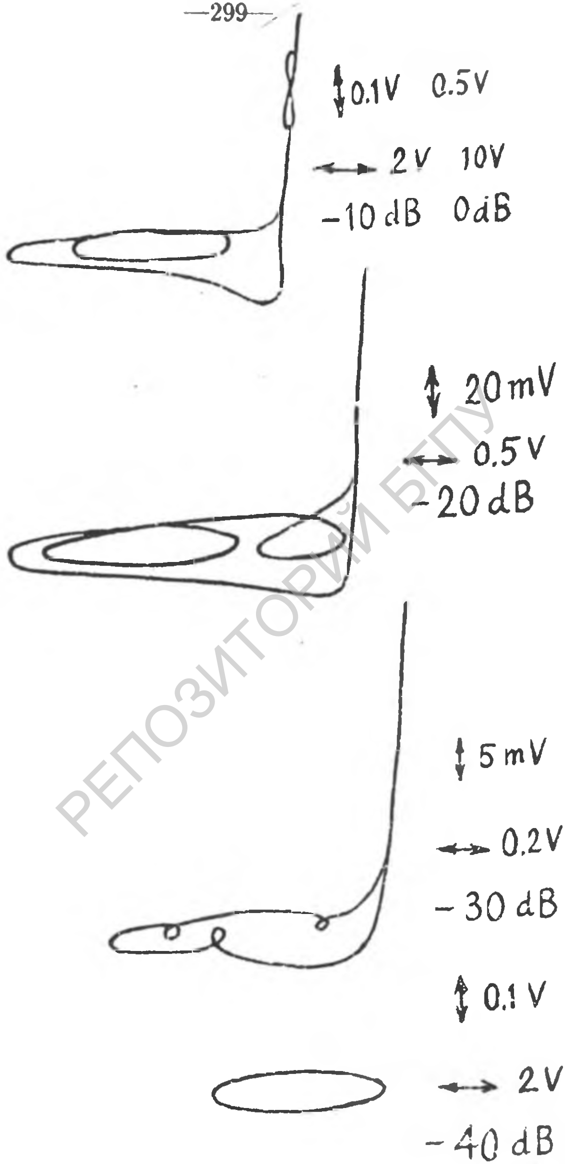

Fig.3 The phase portraits of "diode voltage V — diode current" dependence at the frequency 5000 Hz.

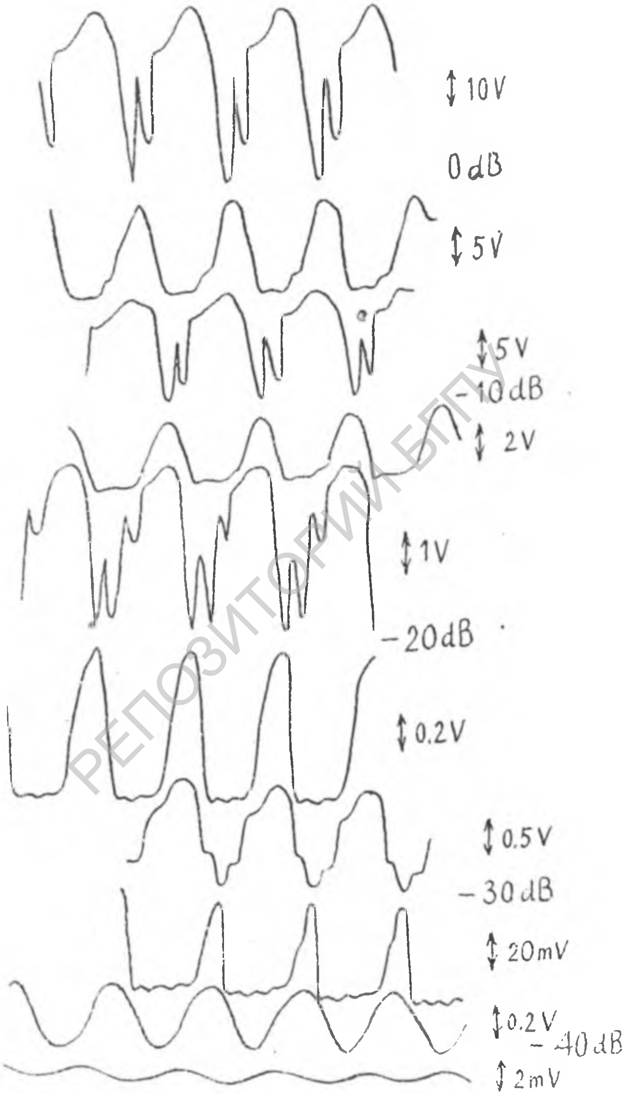

Fig.4. The oscillogrammes of diode voltages V and diode current for the frequency 5000 Hz.

References

[1] *J.Testa. J.Perez, C.Jeffris.* // Phys.Rev.Lett. 1982. L.8. P.714–717.

[2] *J.Gumowski, C.Mira.* Dinamique Chaotique (Collection Nabla). Toulouse. France. Cepardeus Edition. 1980.

[3] *A.Arrour, K.Duhr, M.Halster.* // IEEE Trans. Circuits Syst. 1983. CAS-30. P.913–914.

[4] *A.Arrour, K.Duhr, M.Halster.* // IEEE Trans. Circuits Syst. 1984. CAS-31. P.587–588.

[5] *T.Matsumoto, L.O.Chua, S.Tanaka.* // Phys.Rev.A. 1984. 30. P.1155–1157.