Detector Effect in Microwave Gunn Diode Oscillator with Low-frequency Oscillator Circuit in Bias Circuit

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In the paper features of autodyne detection effect in multicircuit Gunn oscillator with LF oscillator circuit in bias circuit have been investigated theoretically and experimentally. It was found that load alteration in microwave and LF circuits may cause detection signals alteration with the same or opposite signs. It was proved that local minimums and maximums on experimental curves were caused by higher harmonics in output microwave signal of Gunn oscillator.

When microwave radiation power level influenced upon semiconductor elements with negative resistance changes, alterations in their d.c. operation regime are observed. This phenomenon can be understood as detection effect manifestation. If device with negative resistance is an microwave oscillator active element, autodyne detection effect is observed.

The most important sphere of autodyne application is the control of radio- and microelectronics material parameters. Application of autodyne detection effect in semiconductor microwave oscillators for material and structure parameters control is based on discovering of microwave detection signal value dependence on thickness, conductivity and dielectric constant.

One of the methods of autodyne microwave detection signal value calculation with real active element and load parameters, controlled material parameters values area determination, where autodyne sensitivity is as much as possible, mapping out of oscillator construction optimization is the method, based on microwave oscillator equivalent scheme examination, where load complex conductivity is determined by investigated material parameters and equivalent scheme characteristics.

In this paper we describe some results of theoretical and experimental analysis of autodyne detection effect in multicircuit Gunn oscillator section of waveguide with plunger used as load and low-frequency oscillator circuit in bias circuit.

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The microwave detection signal value dependence on plunger position have been experimentally investigated. We used microwave waveguide oscillator with diode AA703 placed into metal post break. LF oscillator circuit was connected to bias circuit through separate capacity in parallel to diode. Microwave frequency was 10 GHz, LF frequency was 10 MHz. For LF oscillations detection КД503А diode was used. Microwave power, d.c. through Gunn diode and detection signals in microwave and LF circuits have been registrated.

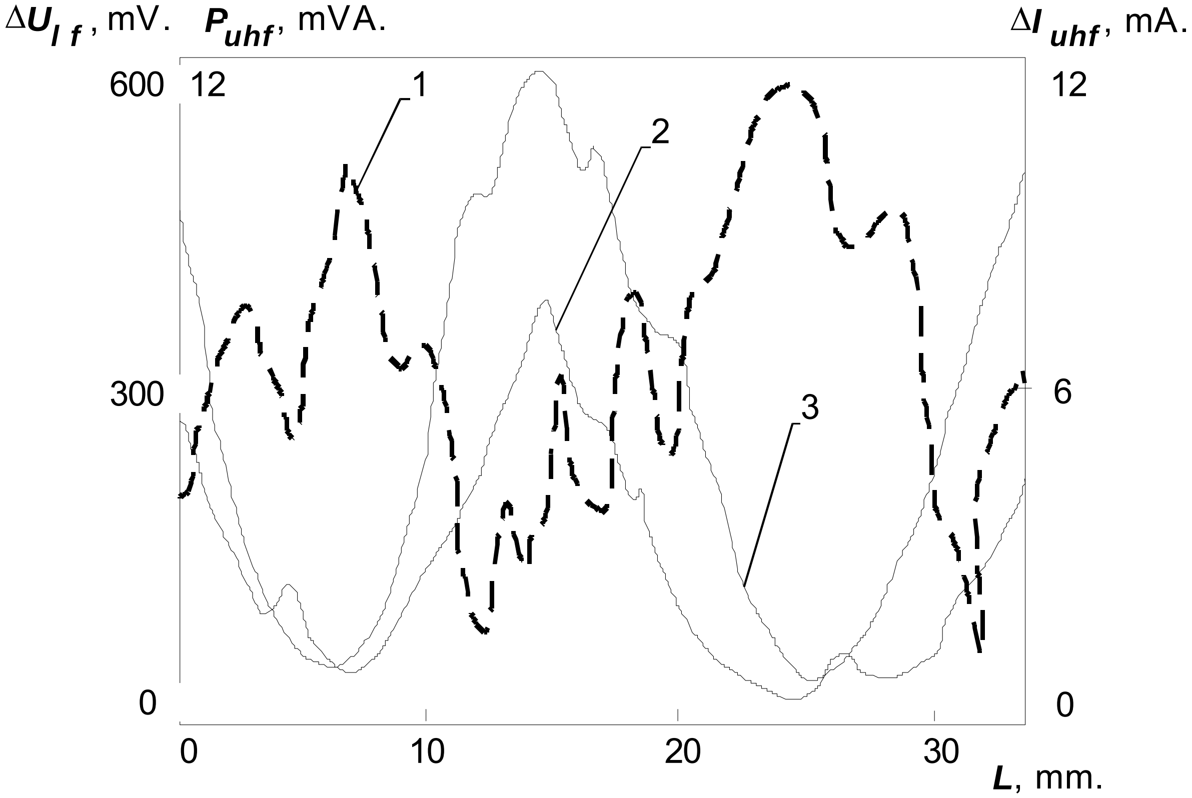

Fig.1. LF and microwave detection signal values (1- ΔU_{lf} and 2- ΔI_{uhf}) and Microwave power dependence 3- P_{uhf} on plunger position.

As a result of experimental reserches it was found that in multifrequency regime the load alteration in microwave circuit (i.e. plunger position alteration) leads to LF detection signal alteration, and that the load alteration in LF circuit (i.e. capacity and inductance alterations) leads to microwave detection signal alteration. These alterations may have identical or opposite signs. From experimental results LF and microwave detection signal values (ΔU_{lf} and ΔI_{uhf}) dependences on plunger position have local minimums and maximums (Fig. 1). Microwave power dependence P_{uhf} on plunger position shown on Fig.1 too.

Theoretical description of Gunn oscillator output signal characteristics was based on mathematics simulation of processes in multicircuit equivalent scheme, which elements model semiconductor structure of Gunn diode in the form of parallel capacity and active nonlinear resistance determined by diode voltage-current dependence, shell elements, microwave resonator in the form of serial and parallel circuits, LF part consisting of serial and parallel circuits, choke in bias circuit, shunt capacity and coupling inductance of diode with LF circuit.

Equivalent scheme is described by system of fourteen differential equations based on Kirhgoff laws. This system nonlinear and it was numerically determined by 4-order Runge-Kutte method with automatic step selection. We used typical Gunn diode voltage-current dependence, that was approximated by expression:

$$I = Sqn\frac{\frac{\mu_0(U+D)}{d} + V_S\left[\frac{U+D}{U_n}\right]^4}{1+\left[\frac{U+D}{U_n}\right]^4}, \qquad \mathbf{(1)}$$

where D=0, if $U \le U_n$, D=2, if $U > U_n$, μ_0 =6000 sm^2/Vs, V_S=8.5 *10^6 sm/s.

Solving this system, frequency dependence of microwave load was took into account. From the decision of the system microwave and LF powers (P_{uhf} and P_{lf}) and microwave and LF detection signal values have been calculated:

$$P_{uhf} = \frac{1}{T}\int_0^T U_{dg}(t) I_6(t) dt, \qquad \mathbf{(2)}$$

$$P_{lf} = \frac{1}{T}\int_0^T U_{kg}(t) I_3(t) dt, \qquad \mathbf{(3)}$$

$$\Delta U_{uhf} = \frac{R_3}{T}\int_0^T I_7(t) dt - R_3 I_{70}, \qquad \mathbf{(4)}$$

$$\Delta U_{lf} = \frac{R_5}{T}\int_0^T I_3(t) dt, \qquad \mathbf{(5)}$$

where I_{70} - d.c. through Gunn diode without generation.

Input load (plunger) resistance in diode’s inclusion plane was determined by expression

$$\mathrm{Im}(Z) = Z_0 \tan(2\pi L/\lambda), \qquad \mathbf{(6)}$$

where Z_0 - impedance of empty waveguide,

L - distance from plunger to diode's inclusion plane,

λ - wavelength in waveguide.

Taking into account **(6),** microwave load parameters of equivalent scheme were calculated from:

$$C_1 = C_{10} + \Delta C \quad \textbf{(7)}$$

$$L_1 = L_{10} \Delta L / (L_{10} + \Delta L), \quad \textbf{(8)}$$

where $\Delta C = -1/(\omega \operatorname{Im}(Z))$, if Im($Z$)<0

$\Delta L = \operatorname{Im}(Z)/\omega$, if Im($Z$)>0.

By detection signal value calculation microwave harmonic oscillations with frequences $4f_0$, $5f_0$, etc. with powers less than 1 p.c. of output microwave power were not considered. f_0 - main harmonic frequency. Theoretical results of microwave and LF detection signal values calculation are presented on Fig.2.

Theoretical calculation showed that plunger position alteration caused microwave power and LF amplitude alteration. It permits to registrate outside detection signal with autodetection signal in bias circuit both on microwave and LF frequences. It was proved that local minimums and maximums on experimental curves were caused by higher harmonics in output microwave signal of Gunn oscillator.

Computer analysis of processes in Gunn diode allowed to determine, that experimentally observed input microwave load areas where load alteration caused detection signals alteration in microwave and LF circuits with the same signs and the areas, where detection signals alteration had opposite signs caused by microwave reactive current component in Gunn's diode availability. At the same time LF circuit parameters alteration more than 100 times causes only very small (less than 5 p.c.) area's boundaries displacement.

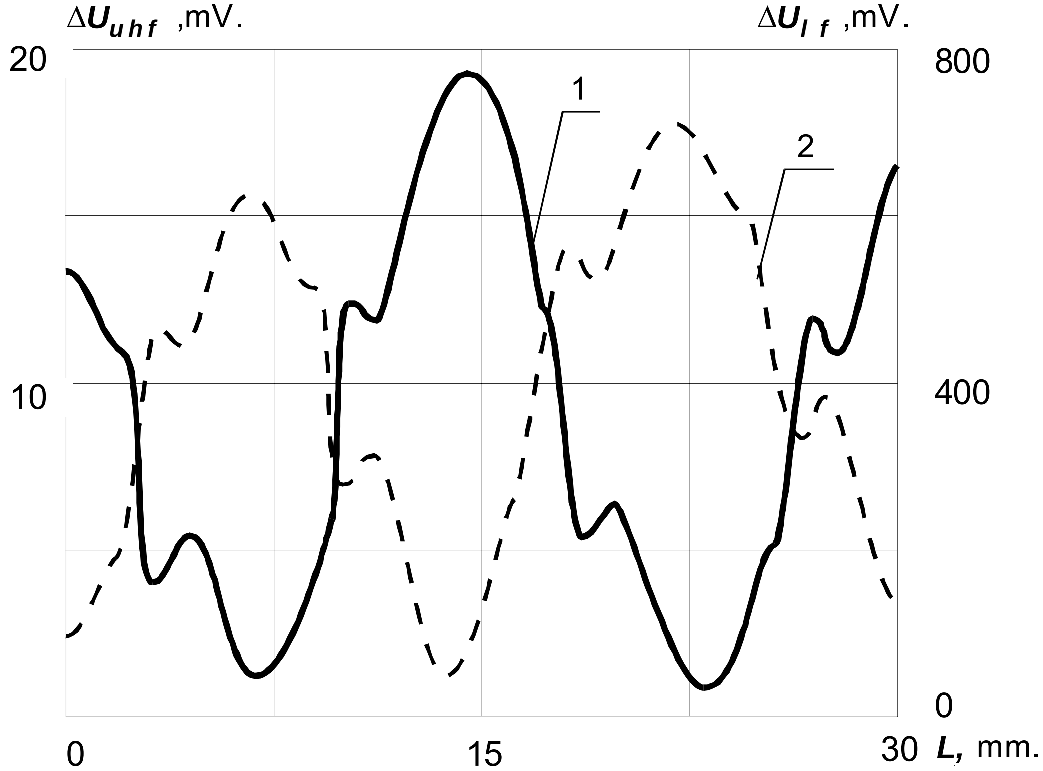

Fig.2. Theoretical results of microwave (1) and LF (2) detection signal values calculation.

Another words in the paper features of autodyne detection effect in multicircuit Gunn oscillator with LF oscillator circuit in bias circuit have been investigated theoretically and experimentally. It was found that load alteration in microwave and LF circuits may cause detection signals alteration with the same or opposite signs. It was proved that local minimums and maximums on experimental curves were caused by higher harmonics in output microwave signal of Gunn oscillator.