ANALYSIS OF OPERATING REGIMES OF EHF HYBRID-INTEGRATED AUTODYNES BASED ON THE GUNN MICROMICROPOWER MESAPLANAR DIODES

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The results of investigations into the operating regimes of EHF hybrid-integrated autodyne generators are given in the present paper. Multipurpose crystals with three mesaplanar structures, one of which serves as an active element and the two others serve as control elements, are used as active elements. The segment of a coplanar strip transmission line are used as a resonant system of the autodyne. The cw regime of autodyne operation and regimes with various types of radiation modulation, which allow the class of problems solved by short-range radar systems to be extended, are examined.

INTRODUCTION

Short-range radar systems (SRRS) based on autodyne principle have a very simple EHF transceiving module, which contains only an antenna and an autodyne generator combining simultaneously functions of the transmitter and the receiver. To extend the autodyne capabilities and the application range and to improve the quality characteristics of sensors developed on its basis, various types of radiation modulation are used. The Gunn multipurpose mesaplanar crystals, with low current consumption in power supply circuits, inserted into the resonant segment of a coplanar strip transmission line [1–4] are promising from this viewpoint.

The cw operating regime of autodynes with unmodulated radiation [5, 6] is most widely used in various SRRS, for example, for measuring the parameters of moving objects. For this operating regime, the low-frequency circuit of the autodyne radar is the simplest one. However, autodynes with various types of radiation modulation, namely, with frequency or pulsed modulation and also with simultaneous pulsed and frequency modulation of radiation of EHF hybrid-integrated autodynes have a higher stability against the ambient noise and wider functional capabilities [7, 8].

1. CW REGIME OF AUTODYNE OPERATION

To analyze the specific features of a cw autodyne signal and application ranges of autodyne systems, we now consider a simplified model of the EHF generator. Figure 1 illustrates the equivalent circuit of the autodyne. In the vicinity of the oscillation frequency $\omega$, the EHF resonator is approximated by the simplest parallel oscillatory circuit comprising the passive parameters of the Gunn diode and consisting of a frequency-independent inductor $L$, a capacitor $C$, and a load with the total conductivity $G = G_r + G_{\text{ext}}$, where $G_r$ is the conductivity of intrinsic resonator losses and $G_{\text{ext}}$ is the conductivity of an external load. Radiation reflected from the object is delayed by time $\tau = \frac{2l}{c}$ (which is generally variable), where $l$ is the distance between the autodyne and the object and $c$ is the velocity of radio-wave propagation.

A generator of current $j_c(t, \tau)$ considers the dependence of radiation on the prehistory of the self-oscillating system, and the circuit of generator power supply and autodyne signal selection is represented by a first-order self-bias circuit (comprising circuit elements $R_0$ and $C_0$). We now write down the system of nonlinear differential equations for this autodyne model with the argument delayed relative to instantaneous voltages $u$ and $U_0$ on capacitors $C$ and $C_0$, respectively in the form

\[ \frac{d^2 u}{dt^2} + \omega_c^2 u = F(u, \dot{u}, t, \tau), \]
\[ \frac{dU_0}{dt} = \frac{1}{T_0} (E - U_0 - R_0 I_0), \tag{1} \]

where

\[ F(u, \dot{u}, t, \tau) = -\frac{\omega_c}{Q_e} \left\{ 1 - \frac{1}{G} \frac{di_c}{dt} \left[ \frac{1}{G} \frac{1}{G} \right] \right\}. \]

Here \( \omega_c = 1/\sqrt{LC} \), \( Q_{load} = \omega_c/G \), \( T_0 = R_0 C_0 \) is the time constant of the self-bias circuit, \( E \) is the voltage on the constant-bias source, \( i_c \) is the instantaneous current through the active element (AE) of the Gunn diode, and \( I_0 \) is the average current through the autodyne power supply circuit. Since \( Q_{load} \) of EHF hybrid-integrated generators based on planar transmission lines are sufficiently high, an approximate solution of the system of equations will be quasi-harmonic one:

\[ u = A(t) \cos \psi(t), \]
\[ j_c(t, \tau) = J(t, \tau) \cos \psi(t, \tau), \tag{2} \]

where \( A(t) \) is the slowly varying self-oscillation amplitude, \( \psi(t) = \delta(t, \tau) + \Delta \delta(t, \tau) \) is the phase of generator oscillations at time \( t \), \( J(t, \tau) \) and \( \psi(t, \tau) \) are the current amplitude and phase of the coupled generator of reflected radiation, \( \delta(t, \tau) \) is the run-on of the phase of the wave transmitted at time \( (t - \tau) \) and arrived at the resonator at time \( t \).

After averaging of Eqs. (1), we obtain the following system of reduced nonlinear differential equations with the delayed argument for the amplitude, frequency \( \omega(t) \), and self-bias of the autodyne generator:

\[ \frac{dA}{dt} = -A \frac{\omega_c (G + G_e)}{2Q_{load}G} + \Gamma(t, \tau) \frac{A\omega_c}{Q_{ext}} \cos \delta(t, \tau), \tag{3} \]
\[ \omega(t) = \omega_c + \frac{\omega_c B_e}{2Q_{load}G} - \Gamma(t, \tau) \frac{\omega_c}{Q_{ext}} \sin \delta(t, \tau), \tag{4} \]
\[ \frac{dU}{dt} = \frac{1}{T_0} (E - U_0 - R_0 I_0), \tag{5} \]

where \( G_e \) and \( B_e \) are the conductance and susceptance of the nonlinear hybrid-integrated AE averaged over the oscillation period of the first harmonic, \( \Gamma(t, \tau) = \Gamma A(t, \tau)/A(t) \) is the modulus of the instantaneous reflection coefficient, \( \Gamma \) is the