

Millimeter Waves Hybrid Devices – Theory and Simulation

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Combination of different types of electronic devices in one engineering design is one of ways of the output characteristics improvement and extension of electronic - wave systems capacities. In the present report the O - type millimeter waves amplifier consisting of resonance and non-resonance stages is theoretically considered that allows to combine in one device the properties intrinsic to different devices (e.g., TWT, orotron, ledatron, laddertron). For research of such construction it is necessary to use two models of electronic - wave interaction appropriate to resonance and non-resonance modes of interaction between a beam and a high-frequency field.

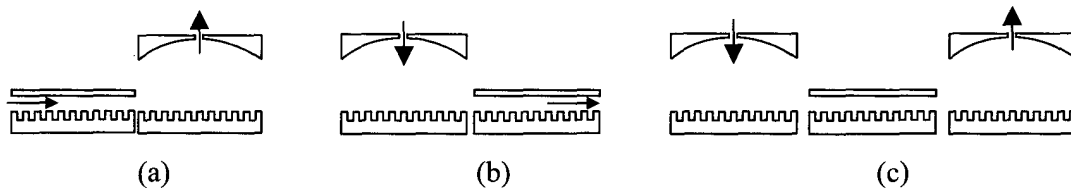


Figure 1. Schemes of hybrid devices.

The multidimensional nonlinear self-consistent theory of electronic - wave interaction in different stages of hybrid devices has been developed. The theory allows to take into account effects stipulated by multiregularity of an interaction space: a high-frequency breaking of electron beam, interaction of electrons with transversal components of a rf fields, beam settling on a slow-wave circuit, space nonuniformity of a rf and static fields etc.

Fig.1 shows different schemes of hybrid devices used for an amplification and transformation of signals. The theoretical model is constructed for arbitrary input signals levels. Therefore, the analysis of multistage systems is possible.

As resonance stages the Smith-Purcell effect devices (orotron, ledatron, etc.) or resonance BWO are used. The nonresonance stages are the planar TWTs.

In Fig.2 we have plotted the steady-state values of amplitude F and phase γ of oscillations in resonance stages of two types - orotron and resonance BWO for different values of an input amplitude represented: (a), (c) – $F_0 = 0.001$; (b), (d) – $F_0 = 0.05$; (scheme in a Fig.1 (a)). The isocurves are plotted for different parameter values $1/G$, where G is proportional to a beam current and quality-factor of the resonator. It is clear that the decrease of the gain at increase F_0 is more conspicuous for an orotron.

The numerical analysis of the electron-wave system displays that the oscillation amplitude decrease takes place in conditions when the amplitude of the rf current first harmonic achieves the maximum. As a result electron bunches are formed acting subsequently in a resonance stage. At a Gaussian envelope function the field strength is weak at the interaction space beginning. Thus the scattering bunches go to the area of the rf field maximum amplitude that stipulates the interaction efficiency decrease.

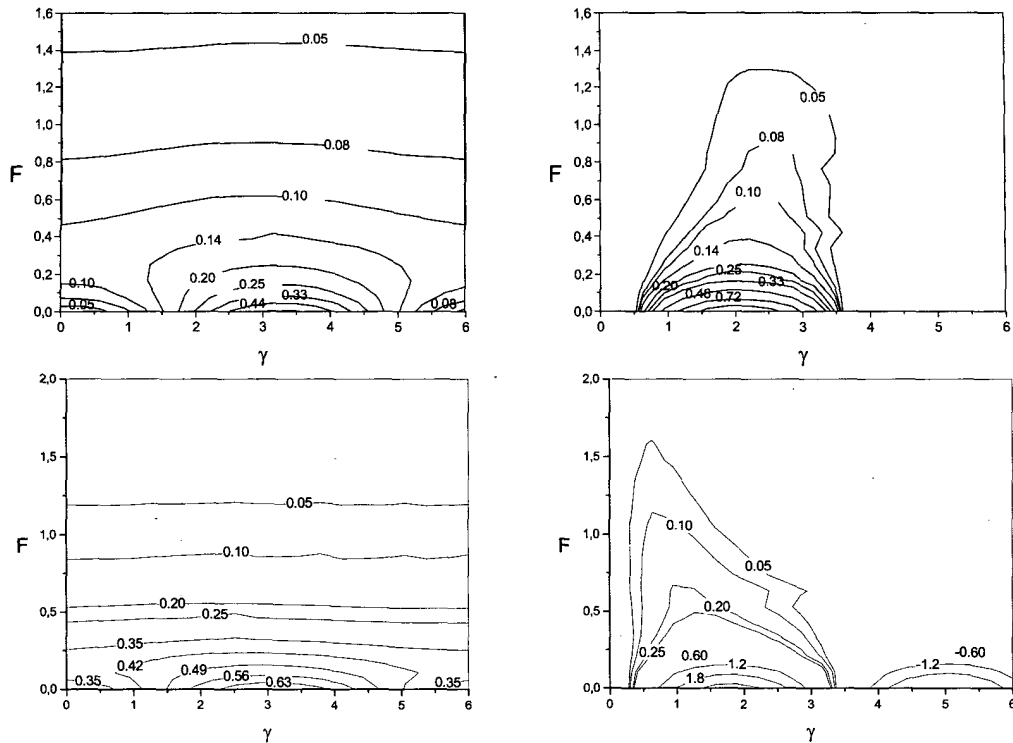


Figure 2. Stationary values for amplitude F and phase shift γ (orotron (a-b) and BWO (c-d)).

Fig.3 shows the spatial distribution of the two-section nonresonance stage electron efficiency (see scheme in Fig.1(b)) for several values of the first section length ξ_1 . In the second section slow-wave structure (grating) is located on a upper slice of the device electrodynamic system. The dashed curve shows dependence of the electron efficiency on longitudinal coordinate for an one-sectional output stage. It is obvious that the application of the inverted nonresonance stage allows to reduce length of the device and to enhance the electron efficiency.

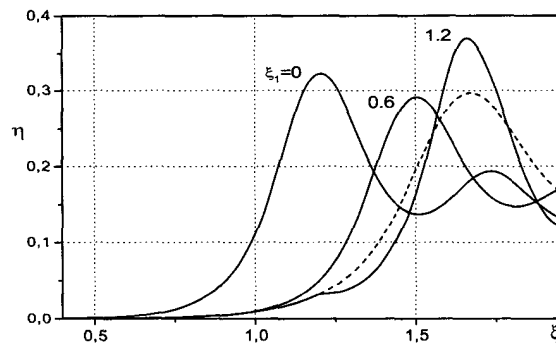


Figure 3. Efficiency vs longitudinal coordinate.