DETECTION USING CENTIMETER-BAND REFLEX KLYSTRONS

R. V. Lebedev

Vestnik Moskovskogo Universiteta. Fizika,
Vol. 33, No. 6, pp. 64-67, 1978

UDC 538.567.2:621,385,623.5

For detection in the microwave band in addition to semiconductor diodes one can use detectors and mixers based on reflex klystrons and traveling-wave tubes, which are practically insensitive to overloads, have large bandwidths, a large dynamic range, and stable and regular parameters.

Experiments were described in [1, 2], and a theory of detection using reflex klystrons and traveling-wave tubes operating under virtual cathode conditions was given in [3, 4]. The traveling-wave tube detectors have high current and limiting sensitivity over a wide band of transmitted frequencies. The operation of a microwave electron detector of this type is based on velocity modulation of the electron beam in the interaction system and on velocity sorting of the electron beam, which produces a virtual cathode in the reflector-resonator space.

To separate the detector signal besides the virtual cathode other velocity analyzers can be employed: crossed electric and magnetic fields, a cylindrical capacitor, a retarding field, and secondary emission. The possibility of using a reflex klystron working under retarding-field conditions as a detector is well known, but there are no publications on the parameters of such a detector.

In this paper we clarify the detection mechanism and obtain the parameter of a reflex-klystron detector under different operating conditions when there is no virtual cathode.

The conditions for a virtual cathode to exist can be estimated using the results obtained in [5]. Hysteresis on the current-voltage characteristic, determined by the presence of the virtual cathode, was not observed.

Experiments were carried out on standard reflex klystrons. The potential of the reflector was varied in such a way that the complete current-voltage characteristic of the klystron $I_r = f(U_r)$ could be plotted. The voltages on the other electrodes depended on the purpose of the experiment and on the possibilities of the klystron, and therefore did not always correspond to the certificate data.

Figure 1 shows a typical current-voltage characteristic of a passive reflex klystron (curve 1). It follows from the graph that when the voltage on the reflector varies, detection occurs in the initial-current region (the retarding-field mode), in the region of current-distribution of the electrons: the return mode, the secondary-emission mode, and the interception mode. The same figure shows the dependence of the detector current (curve 2) on the reflector voltage, the maximum values of which correspond to the electron-return mode. The detector current has a different polarity. Obviously the sign of the detector current is determined by the signal-power level, the form of the current-voltage characteristic, and the position of the operating point on it.

Figure 2 shows the current-voltage characteristic (curve 1) and the dependence of the detector current on the voltage on the reflector for different signal power levels (curves 2, 3 and 4).

The experimental data obtained clearly show that the signal-power level determines the position of the nodal points (the zero and extremum of the detector current) on the current-voltage characteristic. When the signal power is increased, the point where the detector characteristic passes through zero shifts to the right with respect to the origin of coordinates. The dependence of the detector current on the signal power $\Delta I = f(P_c)$ is a

© 1978 by Allerton Press, Inc.

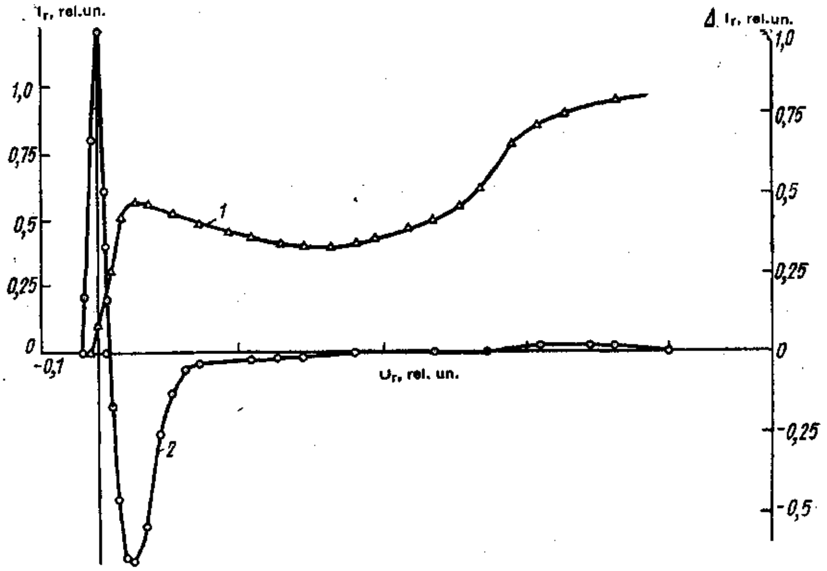

Fig. 1

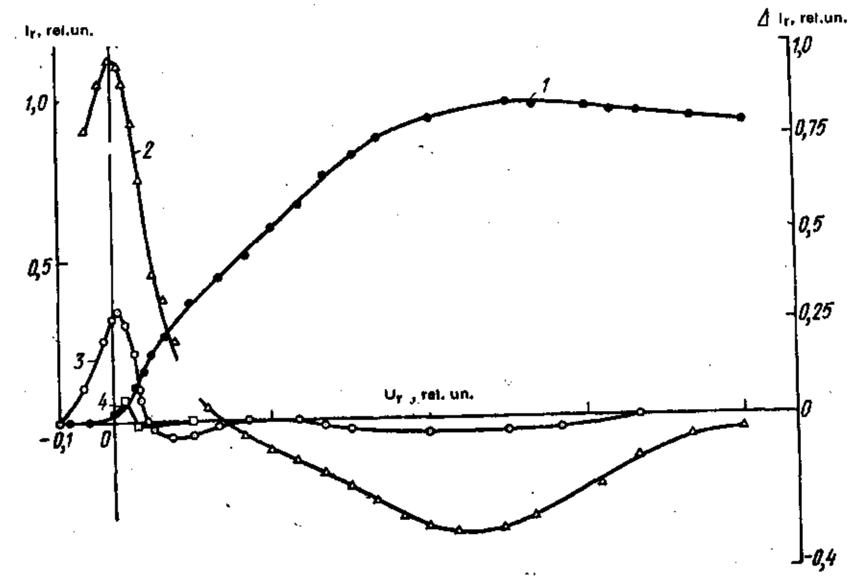

Fig. 2

repeat of the same dependence found in [2], and indicates that the current sensitivity of the reflex klystron increases as the signal power is reduced.

Under retarding-field conditions the current sensitivity, the characteristic of which is shown in Fig. 2, is higher than the current sensitivity of a detector operating under virtual-cathode conditions [2].

Current distribution in the electron-return mode occurs when $U_r < U_p$, when part of the electrons passing through the resonator grid are turned back due to the retarding field which exists in the resonator-reflector gap. A necessary condition for electron return is nonuniformity of the electric field in the plane of the resonator grid, which leads to bending of the electron trajectories. When there is no microwave signal, part of the electrons, due to the action of the retarding field, return to the resonator grid, and only a certain part reaches the reflector and produces a constant component of the current in its circuit. Due to the action of the microwave signal there will be electrons in the electron beam whose energy is sufficient to overcome the retarding field, and there will be a detector current in the reflector circuit.

The current sensitivity is one of the basic parameters both of electron and semiconductor detectors. This parameter occurs in the equation for the limiting sensitivity of electron detectors

$$P_{lim} = \frac{\sqrt{2eI_0 \Delta f}}{k}, \qquad (1)$$

where e is the electron charge, Δf is the passband of the amplifier, I_0 is the current in the resonator-reflector gap, and k is the current sensitivity of the detector, where $k = \frac{\Delta I}{P_c}$.

The value of the limiting sensitivity from Eq. (1) is $1.3 \cdot 10^{-13}$ W/Hz$^{1/2}$. The experimental value of the limiting sensitivity obtained at the noise level of the amplifier is an order of magnitude higher than that given in [2].

We have shown that in addition to existing modes of operation of a reflex-klystron detector there is also the return mode. The detector parameters obtained in the return and retarding field mode, are not inferior to the parameters of semiconductor detectors, but higher than for a detector operating under virtual-cathode conditions.

For operation as a power measurer it should operate in the return mode for which the current sensitivity of electron detectors is a maximum.

The limiting sensitivity of electron detectors is determined mainly by the shot-noise level, produced by the constant component of the reflector current, and depends on the value of the current sensitivity, so that to obtain the optimum receiver parameters one should use the retarding-field mode or the return mode.

In conclusion we thank Yu. V. Gorokhov for his help, and A. I. Kostienko, M. N. Devyatkov and Yu. A. Pirogov for useful discussions.

REFERENCES

1. M. N. Devyatkov and A. I. Kostienko, Radiotekh. i Elektron., no. 5, p. 7, 1962.
2. M. N. Devyatkov, A. I. Kostienko, Yu. A. Pirogov, and S. K. Romanyuk, Elektron. Tekh. Elektronika SVCh, no. 9, 1970.
3. S. D. Gvozdover, Radiotekh. i Elektron., vol. 10, no. 10, 1965.
4. Yu. A. Pirogov, Vest. Mosk. Univ. Fiz. [Moscow University Physics Bulletin], no. 6, 1971.
5. M. N. Devyatkov and G. I. Ovchinnikova, Elektron. Tekh. Elektronika SVCh, no. 8, 1971.

1 June 1976 Department of Radiophysics