INVESTIGATIONS OF PROPAGATION, REFLECTION AND ACTION ON PLASMA OF STOCHASTIC ELECTROMAGNETIC RADIATION

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The broadband generator of stochastic electromagnetic oscillations in a decimetric band of waves lengths with output power ≈ 0,3 W is described. The epitaxial-planar VHF transistors of KT911 type terminated by ring microstrips are used as an active elements. Electrical and amplitude-frequency characteristics of the generator are given. Spectral characteristics of oscillations were investigated by methods of correlation and phase-frequency analysis. We established, that oscillations have non-regular character with appreciable phases jumps.. The stochastic VHF oscillation with such characteristics will be used for investigation of its transmission, reflection and action on plasma.
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It is known [1] that considerable achievements in a progress of plasma electronics are obtained lately, but several of the important questions till now remains insufficiently or at all not investigated. Among them as more important question are theoretical and experimental researches of an interaction of stochastic electromagnetic radiation with substance.

In stochastic electromagnetic fields, an acceleration of charged particles, a heating of plasma [2] and lot of other useful processes can effectively be realized. We remind about fact that there is an exchange of energy between VHF stochastic electromagnetic fields and charged particles, although a pair encounters or synchronism in movement of particles and propagation of electromagnetic fields are absent. In this case, the frequency of pair encounters will acted as a random phases jumps of stochastic oscillations while the averaged over a period energy acquired by a particle is proportional to frequency of phase jumps.

Numerical simulation of transmission, reflection both action of regular and stochastic electromagnetic radiation upon particles of plasma at its incidence on a vacuum-plasma boundary [3] has shown, that monochromatic wave is being completely reflected (except a front), while stochastic wave is being poorly reflected, what is connected mainly with a transmission of pulses into plasma at jumping a wave phase. For a case, when a broadband radiation has same spectral density of energy and width of spectrum, as a stochastic radiation, the transmission factor is on the order less in comparison with transmission factor in a case of a stochastic wave.

Thus, it is possible to state, that the investigation of interaction of stochastic VHF fields with substance will give an essential addition to the theory of interaction and considerably will expand an area of its possible applications.

For experimental investigations of processes features of action of stochastic electromagnetic radiation upon plasma the semiconducting generator of stochastic oscillations was designed and made. Their spectral characteristics were studied. The plan allowing to explore transmission, reflection and action upon plasma of stochastic radiation is offered.

For experimental investigations of processes features of an interaction of stochastic oscillations with a substance it is necessary to have firstly generators of stochastic electromagnetic oscillations, which should agreed to the following main technical requirements:
– the band of generated frequencies should coincided with frequency band of explored systems;
– necessary spectral density of power of stochastic oscillations should be determined;
– the law of distribution of instant values of an amplitude of stochastic radiation should be preset;
– necessary regulation range of power level of stochastic electromagnetic oscillations should be defined;
– output impedance of the generator should be matched with an input wave impedance of coaxial or waveguide transmission line;
– the value of instability of stochastic oscillations level on an output of the generator should be preset at changing of environment conditions (temperature, damp etc.) and of supply voltage.

To satisfy the first and second points of this requirements, as primary noise sources it is necessary to apply such one, the band of generated frequencies which is not less than given frequency band of electromagnetic oscillations. The necessary power level of stochastic electromagnetic oscillations can be obtained with the help of linear amplifier.

A varying of a power level of stochastic electromagnetic oscillations is being realized by a usual method – or on input of the amplifier, or directly by primary noise source.

In consideration of above enumerated requirements on designing such generators, we made the broadband generator of stochastic electromagnetic oscillations, which operates in a continuous mode. Schematic circuit diagram of this generator is shown in Fig. 1.

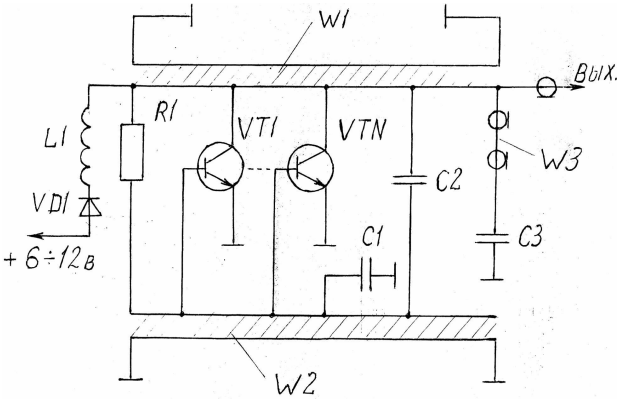

Fig. 1. Schematic circuit diagram of the generator:

W1 and W2 - ring microstrips; W3, C3 – components for matching of generator output; VT1, VTN - epitaxial-planar VHF - transistors; VD1 - diode preventing failure of the generator, at accidental change of power supply polarity; L1 – a filter choke; R1 – resistor presetting a working point of transistors; C1, C2 – condensers, which support necessary back-couplings.

The generator is assembled according to three-dot schema with a capacitive feedback [4] on epitaxial-planar VHF transistors of KT911 type terminated by ring microstrips, and operates in free-running mode. Ring microstrips are the strips of definite sizes, which are etched on bilateral foiling fiberglass. The geometrical sizes of microstrips choose by such, that they were L-C distributed-parameters lines for the given frequencies band, and them wave impedance was 50 ÷ 75 Ω. We managed to expand generated oscillations band and to reduce nonuniformity of amplitude-frequency response by an inserting into the circuitry of additional capacitive negative feedbacks and by a finding of optimum places of their connection on microstrips.

The generator operates in voltage range from 6 up to 12 V and consumed current from 0.3 up to 0.8 A accordingly. The average VHF power of the generator measured by digital wattmeter M3-54 is 0.3 W. The generator has overall dimensions (without the power supply) 140x140x50 mm, and the weight is not exceed 200 g.

For experimental researches of processes features of action on plasma of stochastic electromagnetic radiation it is necessary, first of all, to study spectral characteristics of this radiation. With this purpose we used a method of an obtaining of oscillations realizations and postprocessing them on computer. Autocorrelation functions, correlation times, power density spectrum, temporal fluctuations of oscillation phase were determined by methods of correlation and phase-frequency analysis.

As a result of these researches we established, that the semiconductor broadband generator of stochastic oscillations operating in continuous mode generates oscillations in the frequency band from 20 MHz up to 870 MHz. In Fig. 2 the generator amplitude-frequency characteristic snapshot made from the shield of spectrum analyzer S4-60 is shown.

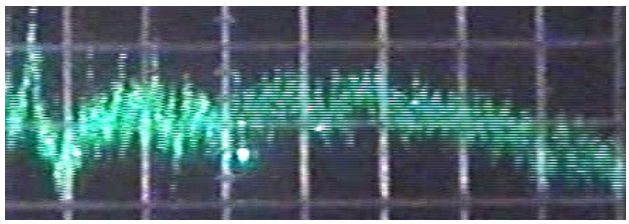

Fig. 2. An amplitude-frequency characteristic of the generator.

Also the realizations snapshots of generated stochastic oscillations made by the cinecamera from the shield of high-frequency oscillograph S7-19 were investigated. From the oscillations realization (the sweep length 30 ns) shown in Fig. 3 one can see that they have non-regular character with appreciable phases jumps.

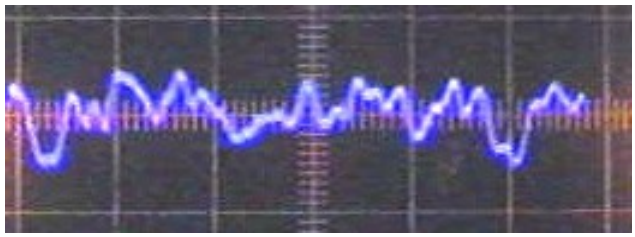

Fig. 3. The oscillogram of high-frequency signal.

The temporary autocorrelation function of oscillations in per-unit is shown in Fig. 4.

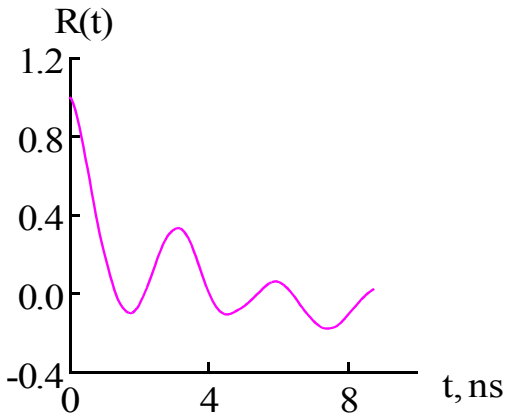

Fig. 4. Autocorrelation function of oscillations.

The times of a correlation of high-frequency oscillations are determined and in our case they are $\tau_{corr} = 2 \div 2.5$ ns. As time of a correlation is related to spectrum width of generated oscillations by a ratio $\tau_{corr} \cdot \Delta f \approx 1$, one can see that wide frequency spectrum corresponds to small times of a correlation. In our case $\Delta f \approx 400 \div 500$ MHz that accords with spectrum half-breadth on the curve of spectral density of oscillations power in per-unit as a function of frequency shown in Fig. 5.

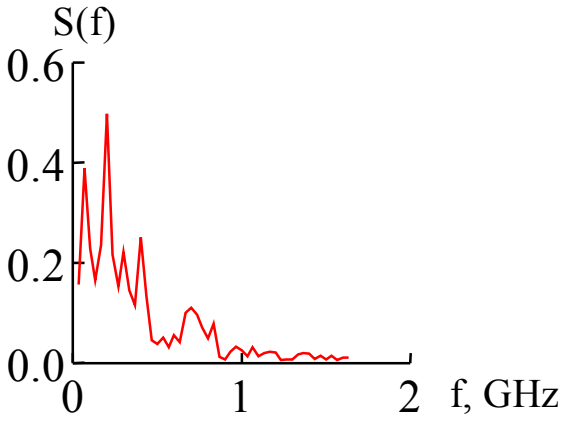

Fig. 5. A spectral power density of oscillations.

It is known that the smaller correlation time and the wider frequency spectrum of oscillations, the larger degree of stochasticity. Therefore in our case the generated VHF oscillations are stochastic. On it points out also existence of phase jumps on the curve of change of total phase φ (in radians) of oscillation as a function of time, where a nonstationarity of behaviour of a frequency-temporary relationship is clearly observed also. The frequency of jumps of an oscillation phase for our case is $f_{jmp} \approx 600$ MHz that one can see in Fig. 6.

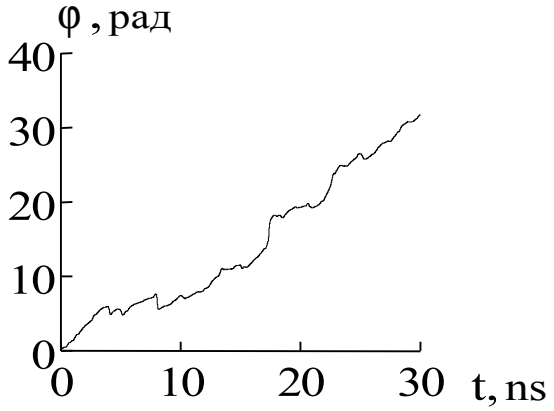

Fig. 6. The oscillations phase as a function of time.

The stochastic VHF oscillation with such characteristics will be used for investigation of its transmission, reflection and action on plasma.

Research of action features of these oscillations upon plasma in comparison with regular ones will be carried out on installation, in which the plasma is created by magnetron operating in continuous mode on wavelength ≈ 12 cm in cylindrical cavity 450 mm in diameter and 500 mm in length.

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