Study of Microwave Generator of Chaotic Oscillations Based on Elements with Lumped Parameters

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ABSTRACT

The paper presents the results of studies of three-point autogenerators operating in emergency mode, namely, as generators of chaotic signals. Studies were conducted to identify common signs of changes in the supply voltage on the parameters of the signals of chaotic generators.

Keywords

Generation, chaotic signals, signal parameters.

1. INTRODUCTION

The development of chaos generators of radio and microwave bands has been underway since the sixties of the twentieth century. Soon after the creation of the jamming generator, the possibility of generating chaotic oscillations in devices based on a backward wave tube and other vacuum devices was shown. In the early eighties, interest arose in the chaos generators of the radio and microwave ranges based on semiconductor active elements, such as transistors [1-3]. Since the mid-80s of the twentieth century, various research teams, both in Russia and abroad, have been actively researching the use of the phenomenon of dynamic chaos for processing and transmitting information. As a practically implemented communication scheme, a model of a direct chaotic information transmission scheme was proposed, in which a chaotic signal is generated directly in the radio or microwave range and modulated by an information signal. It is obvious that the most important part of information transmission systems based on dynamic chaos are the generators of chaotic oscillations. At the same time, they should be used not only as sources of noise-like signals, but also as sources of signals - information carriers. The main objective of this work was the creation of compact devices with low power consumption, reproducible characteristics, as well as the possibility of their easy subsequent implementation. In this case, the focus was on devices based on elements with lumped parameters.

As a result of the work, it was shown that, by scaling accordingly the parameters of the structural elements of the generator and choosing the appropriate active element (transistor), one can obtain chaotic oscillations with frequencies up to several GHz in circuits on lumped elements. The generator is implemented as an experimental model, and its dynamics was studied in the range up to 5 GHz. As an active element, the BFP620 transistor was used; the dimensions of the contact pads connecting the circuit elements were optimized using the Advanced Design System (ADS) circuit design modelling software. The package is developed to design and simulate a wide class of communication devices and systems in the high and ultrahigh frequency ranges and covers the whole range of tasks from developing a conceptual device diagram to solving system level problems. Development of a model for simulations in an ADS package consisted of assembling a generator circuit, choosing a type of transistor, specifying the values of resistor parameters, capacitances and inductances using the package libraries. The chaos generator with 1.5 degrees of freedom was made according to the three-point Scheme and its studies were conducted in various frequency ranges. The study of the operating modes of the generator showed that in the system at low voltages the collector-base and high-voltage emitter-base quite easily multifrequency oscillations occur, but the resulting chaotic oscillations are unstable and exist in narrow zones of the supply voltage of the transistor. The second mode of operation of the generator was observed at high collector-base voltage and low emitter-base voltages. In this case, chaotic oscillations in the system arose almost immediately when opening the emitter-base junction and stably existed when the voltage across the junction changes within small limits. However, the efficiency of the generator was not more than 2%.

The next step was to develop a model of a nonlinear dynamic system with 2.5 degrees of freedom, where a bipolar transistor was used as an active element. With the help of mathematical modelling, it was shown that in such a system one can obtain chaotic oscillations that are close in shape to band oscillations, which is essential for generators of chaotic oscillations used in communication applications. The main results of the study of the dynamics of generators in the ADS package and the results of experiments with them are summarized below. The BFP620 transistor was also used as the active element in the layout, as well as the model. The ratings of the electronic components of the generator coincided with the values of the corresponding parameters used in the simulation of the generator in the ADS package. The results showed that the generator with 2.5 degrees of freedom allows to obtain a stable generation of high-frequency chaotic oscillations in a wide range of control parameters, and using the ADS package to Analyze the generator and taking into account the effect of the board topology and the characteristics of the layout material allows to obtain simulation results that are adequate to experiment.

2. EXPERIMENTAL STUDIES

Experimental studies have established that in the dynamics of a generator, two areas of change in control voltages can be distinguished, in which the system exhibits a fairly stable chaotic behavior. The first is large negative displacements at the emitter-base junction of the transistor (VE = 4–6 V) and small positive ones at the collector-base junction (VC = 0–2 V), and the second is vice versa VE = 1–2 B, and VC = 10–13 V. In this mode, with VE = 5 V and VC = 1.5 V, the current consumption was I = 20 mA. The power of the

output signal was P = 4 mW, and the efficiency ~ 3%. The generation of chaotic oscillations was stable in a fairly wide range of variation of control voltages. During the experiments, several prototypes of generators with 2.5 degrees of freedom were fabricated and investigated. The results obtained at the same time testified to the high repeatability of the operating modes of the generators from sample to sample.
The structural diagram of the experiments is presented in Figure 1.

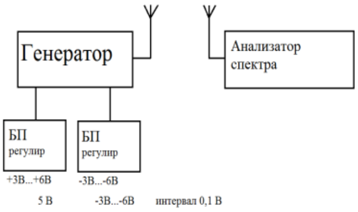

Figure 1 – Block diagram for conducting experiments.

For the experiments, a Rohde @ Schwarz FS-300 spectrum analyzer and two BPL-10 power supplies were used. In the first experiment, a negative voltage of -5.5 V was applied to one input, and the second one ranged from 3V to 6V with an interval of 0.1 V. In the second, a voltage of -5V was applied to one input, and the second one was also changed. In the third and fourth +5.5 V and 5 V, respectively.

3. EXPERIMENTAL RESULTS

Figure 2 shows the resulting harmonic signal. With subsequent voltage changes, its peak frequency shifted to the right. When a voltage of +3.8 V is applied to one input, a chaotic signal appears as shown in Figure 3.
On the basis of the spectra obtained, graphs were plotted for the dependence of peak powers, spectral widths, and peak frequencies on the applied voltages. Figure 4 shows the peak power versus voltage. At the same time, a voltage of +5.5 V was applied to one input, and on the other, it varied from 3 V to 6 V with an interval of 0.1 V (red graph), on the blue graph, + 5 V was applied, and on the other - it varied from 3 V to 6 V with an interval of 0.1 V.

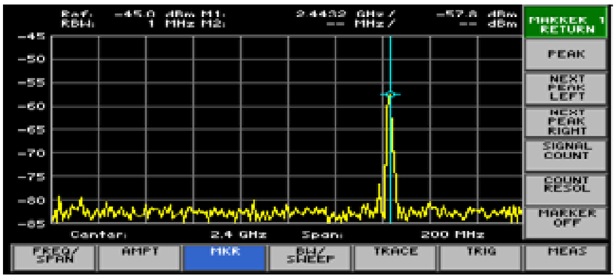

Figure 2 – Harmonic signal spectrum

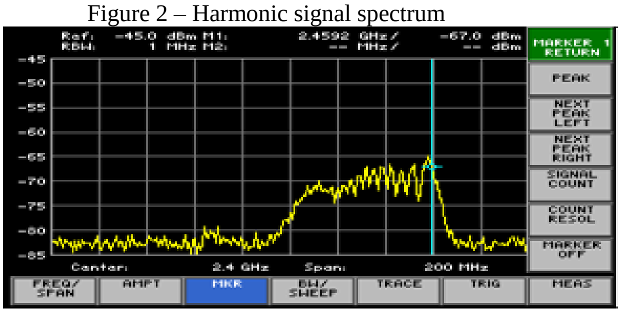

Figure 3 – Chaotic signal spectrum

Figure 5 shows Similar plot, but this time a voltage of -5.5 V was applied to one input, to the other - the voltage varied from 3 V to 6 V with an interval of 0.1 V (red graph), on the blue graph (more wide line) -5 V was applied, and on the other - the voltage varied from 3 V to 6 V with an interval of 0.1 V.

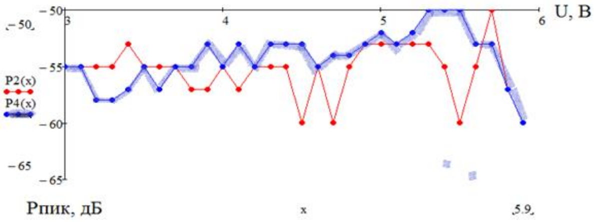

Figure 4–Plots of peak power versus voltage (+5.5V; +5V)

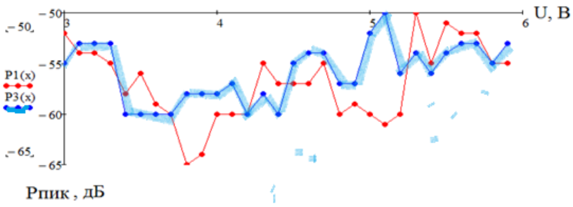

Figure 5–Plots of peak power versus voltage (-5.5V; -5V)

Figure 6 shows the plots of the dependence of the width of the spectrum on the voltage. At the same time, a voltage of +5.5 V was applied to one input, and the voltage varied from 3 V to 6 V with an interval of 0.1 V (red graph) on the other, +5 V was applied to the blue graph, and to the other - from 3 V to 6 V with an interval of 0.1 V.

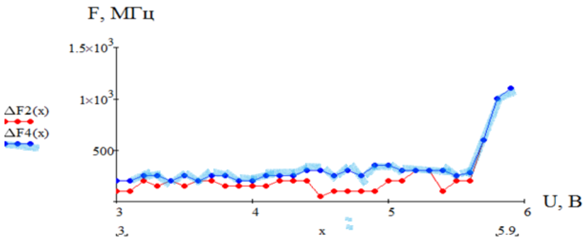

Figure 6 – Plots of the width of the spectrum versus voltage (+5.5 V; +5 V)

Figure 7 shows the plots of the dependence of the width of the spectrum on the voltage. At the same time, a voltage of -5.5 V was applied to one input, and the other voltage varied from 3 V to 6 V with an interval of 0.1 V (red graph), on the blue graph, -5 V was applied, and on the other - from 3 V to 6 V with an interval of 0.1 V.

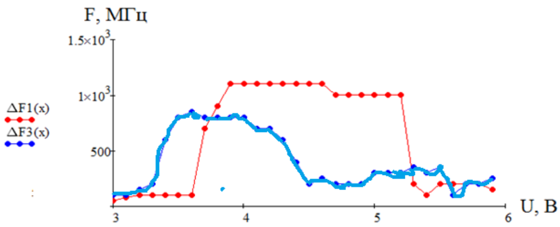

Figure 7–Plots of the width of the spectrum versus Voltage (-5,5V; -5V)

Figure 8 shows plots of peak frequency versus voltage. At the same time, a voltage of -5.5 V was applied to one input, and on the other - varied from 3 V to 6 V with an interval of 0.1 V (red graph), on the blue graph, -5 V was applied, and on the other - varied from 3V to 6V with an interval of 0.1V.
Figure 9 shows the plots of the dependence of the peak frequency on the voltage. At the same time, a voltage of +5.5 V was applied to one input, and the other one ranged from 3

V to 6 V with an interval of 0.1 V (red graph); 3 V to 6 V with an interval of 0.1 V.

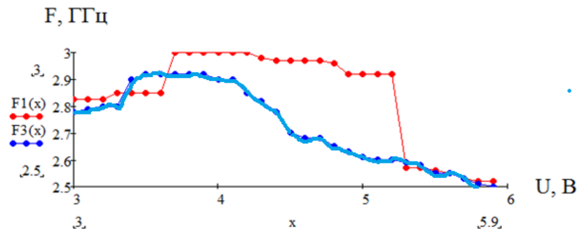

Figure 8 – Plot of peak frequency versus voltage (-5,5V; -5V)

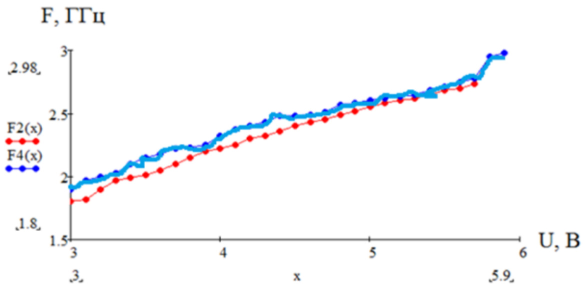

Figure 9 – Plot of peak frequency versus voltage (+5,5 V; +5 V)

Thus, at certain values of the supply voltage, the three-point oscillator of the harmonic oscillations turns into a generator of chaotic signals. It is noteworthy that an abrupt change in the width of the spectrum is a characteristic sign of the appearance of a chaotic signal. The chaotic signal spectrum is broadband. From the graphs of the peak power versus voltage, it can be concluded that when a chaotic signal appears, the peak power decreases sharply and the peak frequency is very sensitive to voltage changes. The results obtained here indicate a high repeatability of the operating modes of the generators from sample to sample.

CONCLUSION

1. The results obtained show that the most important part of information transmission systems based on dynamic chaos are chaotic oscillation generators.
2. Compact devices with low power consumption, reproducible characteristics, and the possibility of their easy subsequent implementation are proposed. Here, the main attention was paid to devices made on the basis of elements with lumped parameters.
3. As a result of the work, it was shown that, by appropriately scaling the parameters of the structural elements of the generator and choosing a suitable active element (transistor), one can obtain chaotic oscillations in circuits on concentrated elements with frequencies up to several GHz.

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