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# Ultra-wideband chaos generator with selected inertia in the microwave range

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An original scheme for constructing an ultra-wideband single-transistor generator of noise-like oscillations of the microwave range of wavelengths was proposed. The generator contains an inertial converter of the output signal of a nonlinear amplifier with positive feedback, the signal of which modulates the supply voltage of the active element (transistor). An experimental model of a chaotic signal generator based on a powerful domestic transistor 2T982A-2 operating in a small signal mode was created. The frequency band of generated noise oscillations with a power spectrum irregularity of 5 dB occupied the frequency range from 2.3 to 7.4 GHz with an integrated power of 5,mW with an average spectral density of noise oscillations of $10^{-6}$ W/MHz. The generator efficiency is 1%.

**Keywords:** powerful bipolar transistor, ultra-wideband spectrum, dynamic chaos, generator with selected inertia.

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The generation of wideband noise signals of the microwave range is closely associated with the design of transistor-based generation systems [1–4]. High-power generator designs often feature a single active element (transistor operating under large-signal conditions) and passive elements and allow one to achieve high energy figures for the output signal in a frequency band up to 15% [4]. The 2T982A-2 high-power silicon transistor with an *n*−*p*−*n*-type epitaxial planar structure is the most prominent example of a transistor of this class produced in Russia. This transistor has been used successfully for several decades to construct high-power sources of wideband microwave chaotic oscillations with an averaged spectral density of noise oscillations of $10^{-3}$ W/MHz and an efficiency up to 15%. Such generation systems are meant to be used in radiolocation and instrumentation systems.

At the same time, the industry is facing an acute problem of construction of simple and reliable sources of ultrawideband (UWB) microwave oscillations with an averaged spectral density of noise oscillations on the order of $10^{-6}$ W/MHz for data transmission systems and internal control over wireless telecommunication devices. Standards IEEE 802.15.4a (for wireless UWB personal area networks) and IEEE 802.15.6 (for wireless body area networks for medical and consumer applications) were introduced to regulate the use of such systems. The IEEE 802.15.6 standard is of interest, since it specifies the individual application of UWB signals on a large scale [5,6]. In addition to their use in personal communications, signals with dynamic chaos properties are applied as data carriers in short-range radiolocation and radio imaging [7,8].

Unlicensed use of UWB signals for wireless communications within the frequency range from 2.85 to 10.6 GHz with a spectral density of noise oscillations up to $10^{-6}$ W/MHz and the corresponding spectral masks for the power spectrum irregularity, which is 3−5 dB, is permitted in Russia, EU countries, Japan, etc. However, in light of the requirements as to the use of allowed spectral densities and spectral masks, the frequency range spanning from 3 to 8 GHz attracts maximum attention. Thus, the design of sources of ultrawideband chaotic oscillations, which operate in the indicated microwave range with a spectral power density in the oscillation band complying with the mentioned standards, is a relevant objective.

In the present study, the potential to construct a 2T982A-2-based generator of ultrawideband chaotic oscillations with their parameters complying with international standards for communications systems is demonstrated.

The IEEE 802.15.4a,b standards impose stringent requirements on the parameters of UWB signals that are allowed to be used for wireless communications in the microwave range. The above-indicated unlicensed microwave range and approved spectral masks provide a viable opportunity to use high-power transistors in such systems. This design of dynamic chaos sources provides for simplicity, reliability, and small size of devices intended to solve the indicated problem.

A self-oscillator based on a 2T982A-2 transistor operating under low-current conditions is proposed to be used to accomplish the task at hand. This choice is dictated by the fact that transistor impedances assume low active values (on the order of 1 Ω) under high-current conditions. Thus, when the active element is operated in the indicated mode, a high Q-factor (close to 10) and, consequently, a standard high-current noise oscillation band, which normally does not exceed 15%, are obtained. Under low-current conditions, the impedance values increase by a factor of 10 or more, while the Q-factor of the system drops below unity. This

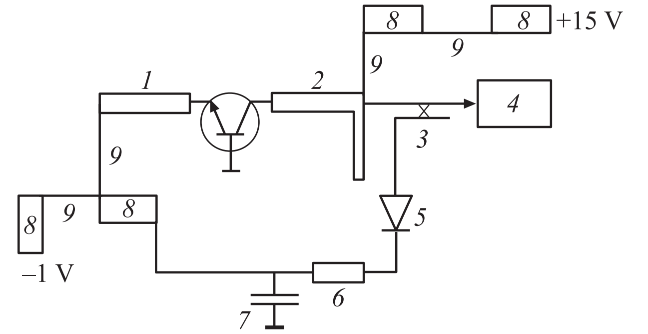


**Figure 1.** UWB - generator with selected inertia in the microwave range. *1* — Emitter matching circuit, *2* — collector matching circuit, *3* — electromagnetic power coupler, *4* — load, *5* — D403V diode, *6* — resistance, *7* — capacitor, and *8* and *9* — elements of power filters based on quarter-wave lines.

allows one to form a net effective noise signal spectrum band that is almost the same as the specified net gain band of the transistor.

The above-mentioned design principles were applied in the present study to construct a noise generator circuit based on a 2T982A-2 transistor operating under small-signal conditions.

The diagram of an UWB chaos generator is presented in Fig. 1. It had the layout corresponding to that of a generator with selected inertia. This layout has been introduced in [9] and provides a fine description of dynamics of single-transistor generators based on high-power bipolar transistors. Specifically, an unambiguous correspondence between the values of parameters of the model of a generator with selected inertia and the values of parameters of actual devices has been established in [1,10]; in addition, the dynamics of this model in the self-oscillating mode has been examined numerically and experimentally to reveal the specifics of emergence and evolution of regular and chaotic oscillations. It has been demonstrated that a generator with selected inertia turns into a source of well-developed chaotic oscillations with a near-normal differential law of probability density distribution at inertia parameter values below 0.06; i.e., an external circuit for inertial conversion of the output signal of an active element is needed to establish the chaotic self-oscillating mode in the system.

The generator model was constructed as a single-transistor system based on a 2T982A-2 high-power transistor in a common-base circuit and was implemented using microstrip technology with 1-mm-thick FLAN-10 material. The input and the output of the transistor were connected directly to 50 Ω-microstrip lines. This transistor matching provides for its operation under low-current conditions. The operating current of the transistor was within 50 mA under nominal supply voltage values. Positive feedback was introduced into the system by internal capacitances of the transistor. The generator entered the self-oscillation mode when the emitter voltage reached −0.8 V. The supply voltages in the experimental model were −1.0 V (emitter)

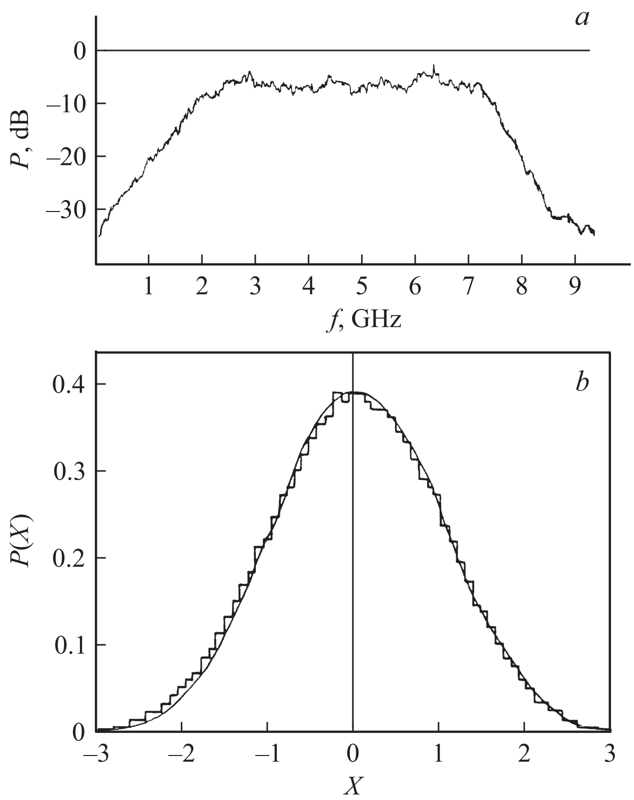


**Figure 2.** *a* — Power spectrum of chaotic oscillations at the generator output; *b* — probability density distribution for chaotic oscillations at the generator output.

and +15 V (collector). The greater part of power of a chaotic signal at the generator output was fed to the load. A fraction of power (20%) was diverted to a half-wave square-law detector circuit that included a D403V diode, which performed half-wave signal conversion, and an *RC*-filter with parameters satisfying condition $g = (fRC)^{-1} = 0.05$, where $f$ is the center frequency of the generator. The filter elements were $R = 300\,\Omega$ and $C = 250$ pF. The output voltage of the inertial converter modulated the emitter supply voltage.

The mechanism of production of chaotic oscillations in the generator was as follows. The application of supply voltages triggered self-excitation of oscillations in the generator. The positive voltage value at the output of the half-wave nonlinear converter started to increase at this point. When the resulting emitter voltage exceeded −0.8 V, the generation process ceased and was repeated again. Thus, the generator output signal was a series of nonregular trains of oscillations with an arbitrary number of unit oscillations and a random initial phase. A Shilnikov-type strange attractor is implemented in the phase space of the system. The presence of a Shilnikov attractor and intermittency are indicative of well-developed chaotic dynamics of the system.

The power spectrum of the output signal of the chaos generator is presented in Fig. 2, *a*. The effective frequency band of generated noise oscillations at a power spectrum irregularity of 5 dB was 2.3–7.4 GHz, the integrated signal

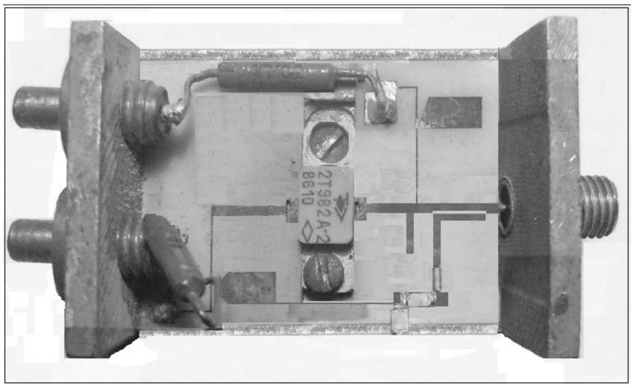


**Figure 3.** Experimental model of an UWB chaos generator.

power was 5 mW, and the resulting averaged spectral density of generated noise oscillations with a normal differential law of probability density distribution was $10^{-6}$ W/MHz (Fig. 2, *b*). The generator efficiency was 1% at an operating transistor current of 50 mA.

Thus, an ultrawideband single-transistor generator of chaotic oscillations with selected inertia in the microwave range was designed and constructed based on a 2T982A-2 transistor produced in Russia (Fig. 3). It was found in the examination of influence of supply voltage variations on the generation of chaotic oscillations that a significant (up to 15%) reduction in the collector supply voltage did not disrupt the generation of chaotic oscillations, although the integrated generator output power decreased (to 55%). The chaotic generation mode is stable against changes in the temperature of the base of the generator body (to which the transistor base is secured) within the range from $-30$ to $+60^\circ$C. This resistance to external influences coupled with fitting parameters of the output chaotic signal make the generator well-suited for devices operating in compliance with standards IEEE 802.15.4a (for wireless UWB personal area networks) and IEEE 802.15.6 (for wireless body area networks for medical and consumer applications) and for electronic countermeasures systems and active short-range noise radiolocation systems.

It should be noted that the obtained results of experimental examination of the UWB transistor generator with selected inertia in the microwave range suggest the possibility of its implementation based on other types of active elements with the slope of their dynamic characteristic depending on supply voltages.

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## Conflict of interest

The authors declare that they have no conflict of interest.

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