Radiopulse generation in dispersive nonlinear transmission lines with GaAs S-diodes

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Abstract. The article discusses the regularities that increase the efficiency of generation of microwave oscillations in nonlinear dispersive lines with commutation diodes. GaAs semiconductor structures were used as switching diodes. The results of numerical simulations and experiments are presented, showing that the amplitude of microwave oscillations in the line increases with decreasing oscillation frequency.

1. Introduction
The search for new sources of ultra-wideband microwave pulses is of interest for research in the field of electromagnetic compatibility, short-pulse radar, noise oscillators, etc. [1,2]. In previous works, a promising method for generating microwave oscillations was described using a coaxial line with a corrugated central conductor, in the gaps of which switching sharpening diodes are placed with a certain period, which can be GaAs S-diodes or Si SOS-diodes [3,4]. The use of semiconductor diodes as nonlinear elements has such advantages as simplicity of design, durability, and pulse repetition rate. Recent studies have shown that both types of switching diodes can excite short microwave pulses [5,6]. In [6], for example, it was shown that in a diode line with GaAs diodes, designed for an oscillation frequency of 1 GHz, microwave oscillations were excited with a swing of less than 10% relative to the amplitude of the modulating pulse. In this paper, we investigate possible ways to increase the efficiency of generation of microwave oscillations.

2. Simulation of RF excitation in a line with switching diodes

2.1. Model Description
In the numerical model, the dispersion line was a coaxial waveguide with a central corrugated conductor consisting of 10 sections with varying diameters. Switching diodes were placed in the gaps in the conductor. The line is filled with vacuum oil with a dielectric constant of 2.2. The modeled structure in section is shown in figure 1.
The switching diodes in the model were designed in the form of small cylinders consisting of a material whose conductivity sharply changes from 0 to $10^7$ S/m in 0.4 ns when a voltage pulse passed. The geometrical dimensions of the corrugated structure were selected so that the frequency of the generated oscillations was approximately 600-700 MHz. The coaxial line was excited by a trapezoidal voltage pulse with a duration of 5 ns at half maximum and with a rise and fall of 0.9 ns. The pulse amplitude was 1 V.

2.2. Simulation results
Figure 2 shows the voltage pulses recorded at the input and output of this line for the case when short-circuited jumpers are inserted instead of diodes, and for the case when 10 diodes with their own capacitance of 0 pF are placed in the gaps.

It can be seen from the figure 2 that when the diodes are triggered, the oscillation amplitude increases significantly compared to the case without diodes.

Then, parallel to each of the diodes, capacitors of 0, 20, and 80 pF were added. In each case, an output voltage pulse was recorded at the output of the line.
It can be seen from the figure 3 that with a decrease in the capacitance of the diode and the constructive capacitance of the contacts, the amplitude of the microwave oscillations increases. This result shows the possibility of further increasing the efficiency of generation of microwave oscillations in such a design.

In addition, a numerical simulation was carried out for the case when only two diodes were installed in the line in the second and third sections. Output voltage pulses were recorded for the case when the line was filled with air or oil. In the latter case, a capacitance of 20 pF was also added to each of the diodes. Figure 4 shows the recorded pulses for three cases.

The oscillograms show that again with an increase in the capacitance of the diodes, the amplitude of the oscillations decreases. At the same time, it becomes smaller even than in the case when the line is filled with air. In addition, figure 2 and figure 4 shows that as the number of diodes increases, the oscillation frequency increases.

3. Experimental results
Compared with [6], to achieve a generation frequency of 670 MHz, the length of the corrugated structure section was increased from 40 mm to 65 mm. The voltage pulse generator described in [7] was used.
Figure 5 shows a scheme of the experiment. At the very beginning, metal jumpers were placed in the gaps of the conductor. A trapezoidal signal with an amplitude of 3 V, a duration of 10 ns, and a leading edge of 0.5 ns from a G4-85 pulse generator was fed to the line input via a coaxial cable. The output signal was modulated by microwave oscillations. In the course of performing “cold” experiments, two cases were investigated: when the line was filled with vacuum oil with epsilon 2.2 and when the line was not filled with oil.

![Figure 5. Scheme of experiment.](image)

Figure 6 shows that when the line was not filled with oil, the rise time increased significantly from 500 ps to 2 ns. The period of the excited microwave oscillations was 1.4 ns, which corresponds to a frequency of 710 MHz. At the end, an increase in the pulse amplitude is visible, which is associated with a slight mismatch between the diode line and the coaxial connector.

![Figure 6. The G4-85 generator voltage pulse at the output from the line without oil.](image)

When the line was filled with oil, the microwave frequency was 590 MHz (figure 7). It can be seen that the shock oscillation of the amplitude is significantly lower in the line with oil.
In the “hot” experiment, instead of the G4-85 generator, the generator described in [7] was used as a source of voltage pulses. Figure 8 shows an oscillogram of a voltage pulse at the output of a line with two diodes.

The amplitude of microwave oscillations was 780 V, which is 42% of the voltage pulse amplitude. At the same time, in [5, 6], the swing did not exceed 500 V at a significantly higher amplitude of the input pulse.

Figure 9 shows an oscillogram of a voltage pulse at the output from a line that was filled with vacuum oil.
Figure 9. Voltage pulses with microwave oscillations in the line with vacuum oil.

It is seen that the oscillation period in this case corresponds to a frequency of 480 MHz. The oscillation amplitude is approximately 670 V, which is less than in the line without oil. However, as a percentage of the voltage pulse amplitude, the swing is already 65%.

4. Discussion
Taking into account the previous work [5], numerical simulation showed that an increase in the length of the section in the line leads to a decrease in the frequency of microwave oscillations. In this case, the oscillation amplitude increases, despite the fact that in this work the voltage pulse front edge was larger than in [5], namely 0.9 ns. Experiments have shown that in the line with an increased length of periodic sections, the amplitude of microwave oscillations increases by more than 50%, with a reduced amplitude of the input voltage pulse in comparison with results of previous works. Experiments also indicate that, in all possibility, a decrease in the design capacitance of contacts between the line sections and diodes should lead to an additional increase in the amplitude of microwave oscillations.

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