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Broadband Pulsed Generator Based on H-waveguides

Contents

Abstract

Results of the computer simulation and experimental study of high-power broadband microwave generator, based on H-waveguide are presented. H-waveguide was driven by the high-voltage dual spark gap. The spark gap is filled by the pressurized gas, serving as load of the dual forming line. The generator allows to obtain power in pulse up to 400–450 MW for the spectrum width $\Delta\omega/\omega \sim 0.5$ and PRF up to 10 Hz.

1. Introduction

Generation of broadband pulses with complex waveform and spectrum is of essential interest for numerous applications. These pulses can be formed by the high-power generators with spectrum width $\Delta\omega/\omega \sim 0.5$. In comparison with UWB signals generators they allow to obtain higher spectral power density and design effective antennas for transmission and receipt of these signals.

Design of this generator has been first described in the study [1] and is based on the direct driving of H-waveguide by the gas-filled spark gap. In this work, design of the dual spark-gap and mirror antenna with customized excentric broadband feed. Dual spark-gap design includes correcting capacitor. Designed shape of the mirror antenna provides high directivity of transmitted radiation.

Further studies results of these generators are presented. Main attention is paid to the numerical simulation and experimental studies, targeting increase in operation efficiency and power level of the generated emission, as well as generation of emission with required spectra and waveforms.

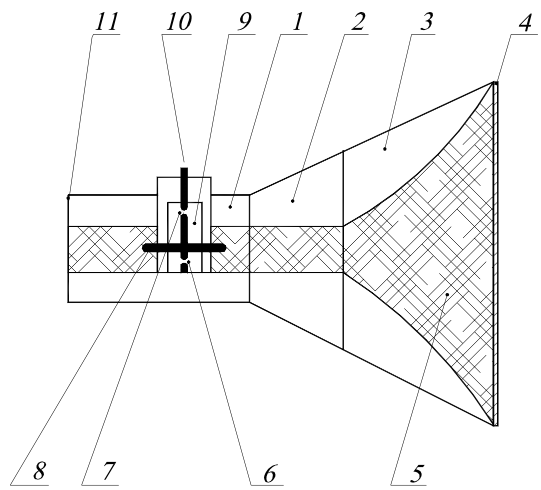
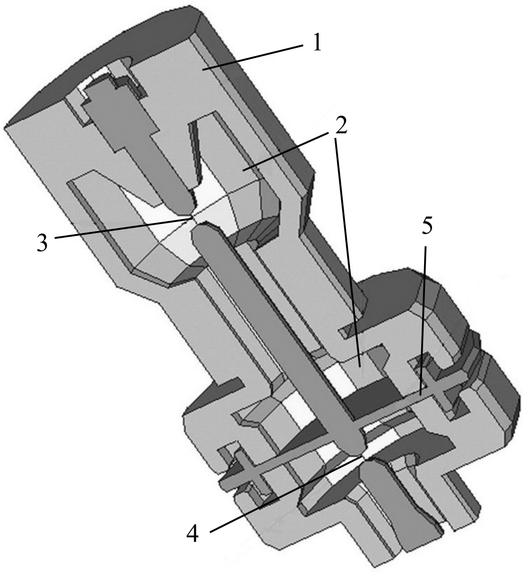


Fig. 1. Design of the broadband pulsed generator based on H-waveguide: 1 is H-waveguide; 2 is junction; 3 is horn radiating element; 4 is sealed coupling window; 5 is transformer oil; 6,7 are gaps of the exciting spark gap; 8 is correcting capacitor; 9 is gas-filled spark-gap; 10 is high-voltage electrode; 11 is back conductive wall.

2. Generator description

Schematic diagram, illustrating design of the H-



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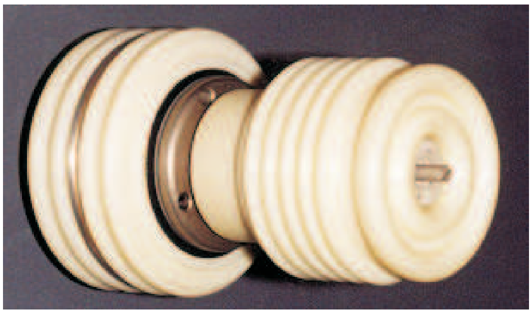
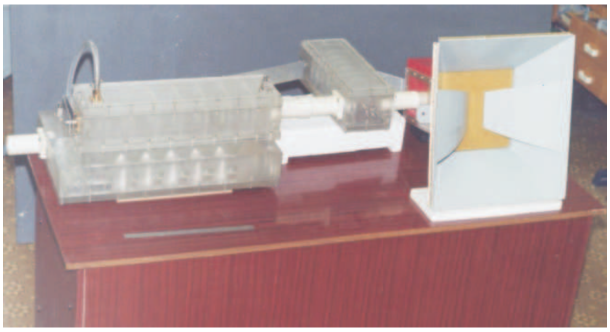


(b)

Fig. 2. Schematic diagram of dual spark gap (a) and its photograph (b): 1 is dielectric case; 2 are spark chambers; 3 is peaking spark gap; 4 is driving spark gap; 5 is disk corrector capacitor.



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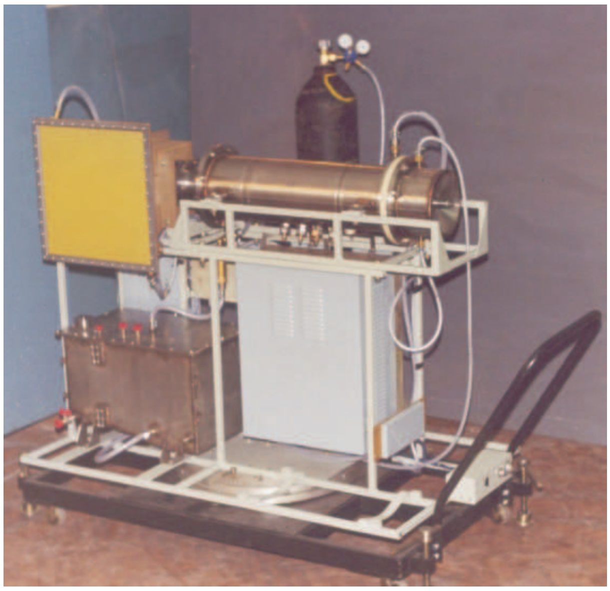


(b)

Fig. 3. Photo of H-waveguide generator with the dual spark-gap, driven by the Marx generator with intermediate capacitor storage (a) and with blumlein line driving (b).

waveguide based generator is shown at the Fig. 1.

Generator is designed as the rigged waveguide (H-waveguide) (1) with matching junction (2) to the complex shape horn with rectangular output section (3), covered by RF transparent cover. Driving spark gap with two gaps (6) and (7) is positioned directly in the H-waveguide so that the driving spark gap (6) resides in the area with maximal electric field strength of the H-waveguide main mode. Plasma discharge channel is parallel to the main mode E-field vector.

Spark-gap, whose design and photograph is shown at the Fig. 2(a,b) is made in the form of self-contained design, inserted in the H-waveguide.

Spark-gap is filled by N_2 or SF_6 gas under the pressure up to 18 atmospheres. The spark-gap is driven by the high-voltage capacitor storage or blumlein.

Another generator modification was studied experimentally, where the coaxial-waveguide junction was driving H-waveguide. In this case, generator was excited by the spark current, shaped in the dual forming line by 3ns pulses. Dual forming line is charged by the Tesla transformer with output voltage up to 300 kV. Photograph of the generator with gas-filled spark gap is shown at the Fig. 3(a). Photograph of the generator with dual-forming line driver is shown at the Fig. 3(b).

Both generators utilized self-contained power supply based on the solid-state voltage upconverter, providing operation with 10 Hz repetition rate.

3. Computer simulation results

Computer simulation study addressed matching of the generator electrodynamic structure (EDS) in the operation frequency band depending on certain parameters of the generator design and driving pulse shape. Simulated design for the generator is shown at the Fig. 4.

Simulated generator had the following H-waveguide

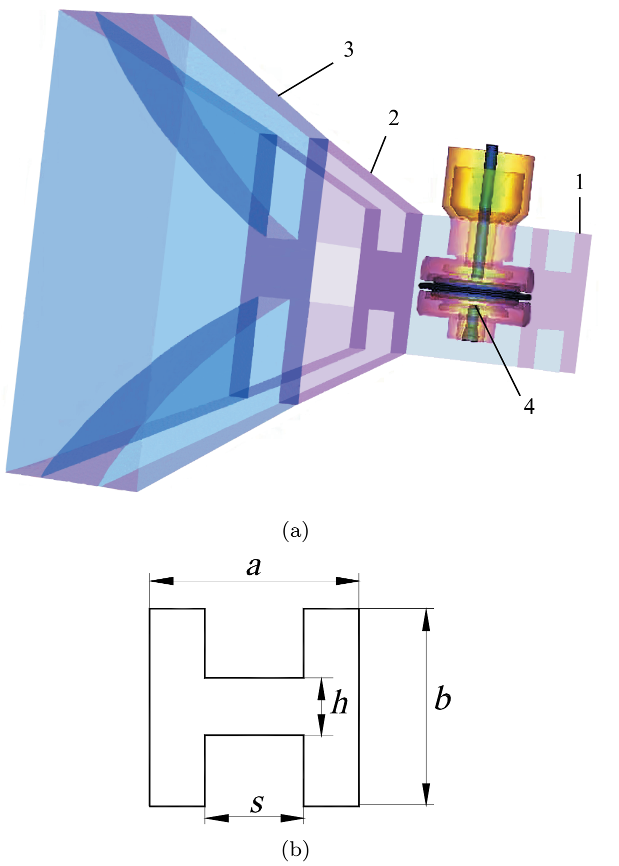


Fig. 4. Configuration of H-waveguide used in computer simulation (a) and its cross section (b): 1 is *H*-waveguide; 2 is matching junction; 3 is horn radiator; 4 is driving spark-gap.

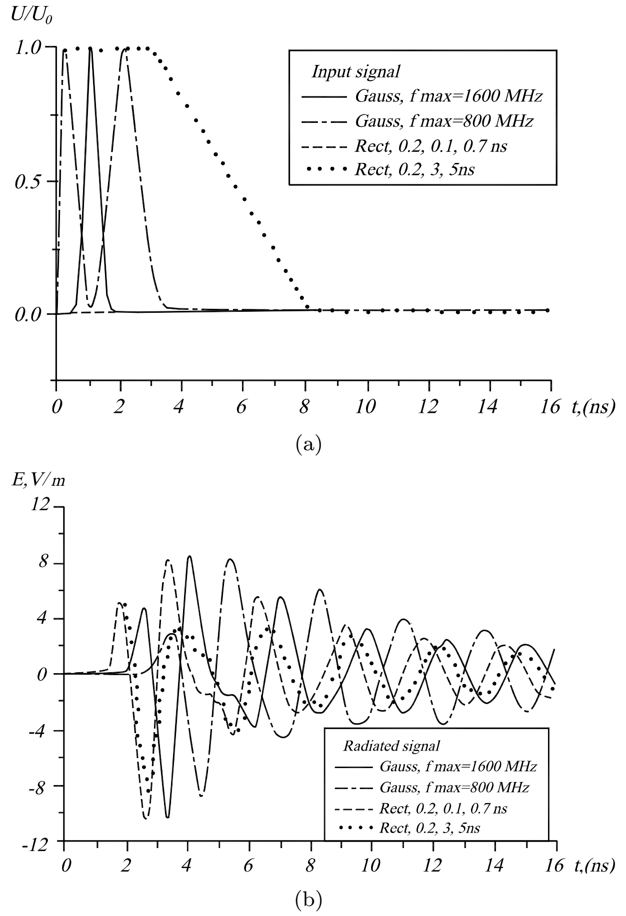


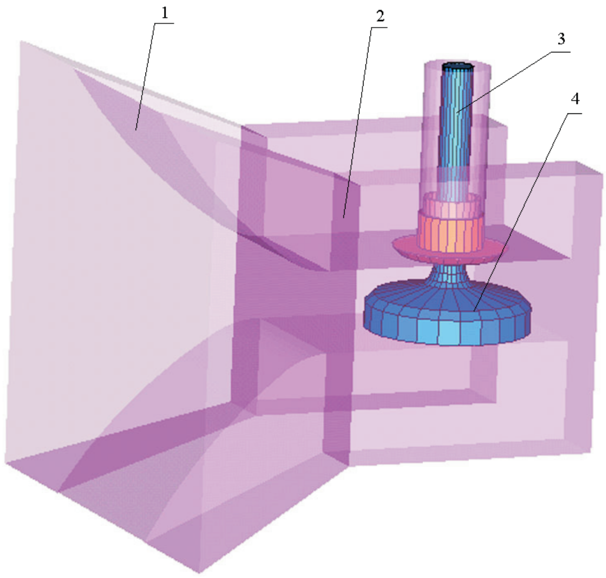
Fig. 5. Waveform of H-waveguide exciting pulses (a) and E-component waveform for the radiated signal (b).

dimensions: a = 180 mm; b = 120 mm; s = 80 mm; h = 50 mm. Horn aperture size is 450 × 400 mm. Internal waveguide cavity (excluding the spark-gap volume) is filled by the purified transformer oil with permittivity $\varepsilon = 2.3$. The driving pulse, shown at the Fig. 5(a) was approximated by the Gaussian pulse with the spectrum width 1.6 GHz and 0.8 GHz or piecewise-linear function with the lengths of top, leading and trailing edges, as shown at the Fig. 5 (a). Fig. 5 (b) displays oscilloscope traces, recorded by the perfect probe at the distance of 25 mm from the horn aperture for different shapes of driving pulses.

The data, shown at the Fig. 5, correspond to the excitation of the structure with 5 Ohm output impedance by the signal with unit power. The signal is connected to the spark-gap of the virtual source. It can be seen from the presented data that for the short driving pulses, the form of radiated signal is virtually independent on the driving pulse parameters. Two characteristic components can be isolated in the transmitted signal — basic bipolar signal and post-pulse oscillations. Quasi-period of the main signal and respective entire signal spectral component are determined by the dispersive waveguide characteristics and distance from the spark-gap to the waveguide back wall. No simulation of the driving spark-gap has been performed in the framework of the project, so spark-gap impedance have not been found. In view of this, radiated signal amplitude was studied as a function of the driving spark gap impedance. The impedance values, close to the realistic, have been shown to provide efficiency less than 10–15 % for any spectral component of the driving signal transfer to the radiated signal.

Performed driving system computer optimization showed that the most effective method to excite H-waveguide is utilization of optimized in the required frequency band coaxial-waveguide junction of the special "button-like" type (hereinafter BCW). A design of this structure is shown at the Fig. 6(a). Results of computer simulation are presented at the Fig. 6(b). Excitation signal is Gaussian pulse. For the sake of comparison the signal in the same point is presented if the BCW is replacted by the spark-gap, equal to the impedance of coaxial line (≈ 30 Ohms).

It can be seen from the presented data that when H-waveguide is excited by BCW the amplitude of input



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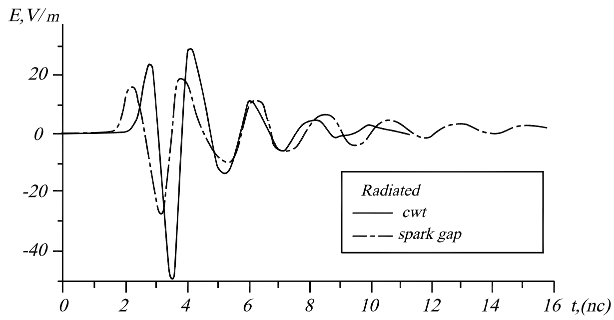


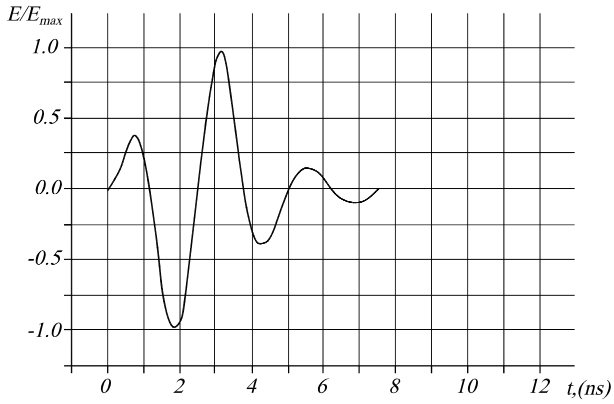
(b)

Fig. 6. a – Computer simulation of H-waveguide excitation by the "button-like" coaxial waveguide junction: 1 is broadband horn antenna of special shape; 2 is H-waveguide; 3 is coaxial line; 4 is "button"-like electrode. b – E-component waveform for the spark-gap and coaxial-waveguide junction excitations.

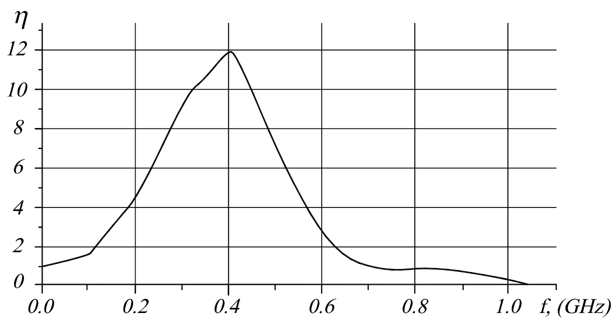
signal is by a factor of 1.8 higher than that in case of the direct driving by the spark gap. In this case, post-pulse oscillations, whose period is determined by the dispersion properties of the waveguide, diminish faster. Despite the higher efficiency, BCW excitation requires effective driving pulse forming system. This requirement implies higher system weight and size. At the same time, generator with the direct excitation by the spark gap is simpler, more compact and does not require dedicated pulse shaping device.

4. Experimental results

Several types of H-waveguide based generators have been tested. Basic characteristics of the H-waveguide unit were virtually identical with the excitation system being the main difference. Consequently, this lead to certain differences in the output



(a)



(b)

Fig. 7. Typical experimentally measured waveform and spectrum of a generator.

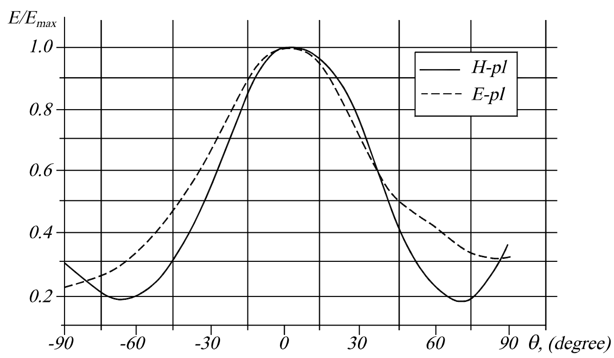


Fig. 8. Measured beam patterns in E and H planes without reflector.

characteristics of the radiation. Fig. 7(a,b) displays typical experimentally measured waveforms and spectra of a measured generator. Fig. 8 shows measured E and H planes beam patterns without reflector mirror.

Peak measured power in the generator is 400–450 MW and achieved for the amplitudes of the driving pulse up to 300 kV. Further increase of the driving pulse magnitude leads to the essential increase of the radiated power.

5. Conclusion

The study results confirmed good prospectives of H-waveguide horn structures for the forming and radiation of broadband pulsed signals with the spectrum width $\Delta\omega/\omega \sim 0.5$. Their advantage is simple and compact design as well as feasibility to implement effective directive antennas with low level of the side and back lobes. Experimental results qualitatively correspond to the simulation results.

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References

[1] Somov V.A., Chepurnyy Ya.N., Tkath Yu.V., Kucherenko V.A. Non-Sine Impulse Waveform generator // Electromagnetic Phenomena. – 2001. – V. 2, N 1(5). – P. 118–123.