

# BROADBAND PULSED GENERATOR BASED ON H-WAVEGUIDE

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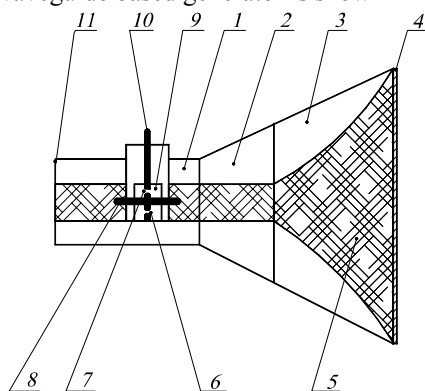
back conductive wall

## Abstract

Generation of broadband pulses with complex waveform and spectrum is of interest for numerous applications. These pulses can be formed by high-power generators with spectral bandwidths of  $\Delta\omega/\omega \sim 0.5$ . Unlike ultra wideband (UWB) signal generators, broadband generators generate higher spectral power densities and have available effective antennas for transmission and receipt of these signals. The design of this generator was first described in [1] and is based on the direct driving of H-waveguides by gas-filled spark gaps. In this paper, the design of the dual spark-gap and of a mirror antenna with a customized broadband feed structure is presented. The dual spark-gap design includes a correcting capacitor. The designed shape of the mirror antenna provides high directivity of the transmitted radiation. In addition, the results of numerical simulations and experimental studies, targeting an increase in the operational efficiency and the radiated power levels of the generators, as well as the generation of radiation with the required spectra and waveforms, are presented.

## I. Generator description

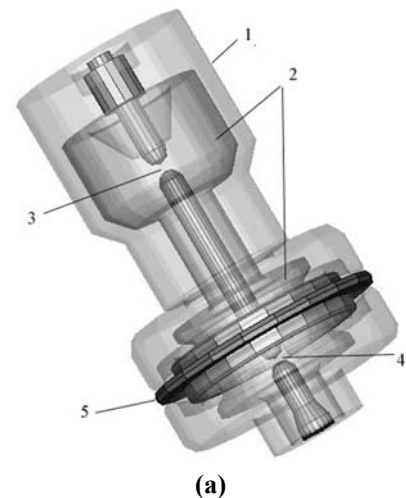
A schematic diagram, illustrating design of the H-waveguide based generator is shown in Fig. 1.



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

The generator consists of a rigged waveguide (H-waveguide) (1) with matching junction (2) to a complex shaped horn with rectangular output section (3), covered by a RF transparent cover. A 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 where the maximum electric field strength of the H-waveguide is the main mode. A plasma channel in the spark-gap is parallel to the main mode E-field vector.

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



(a)



(b)

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

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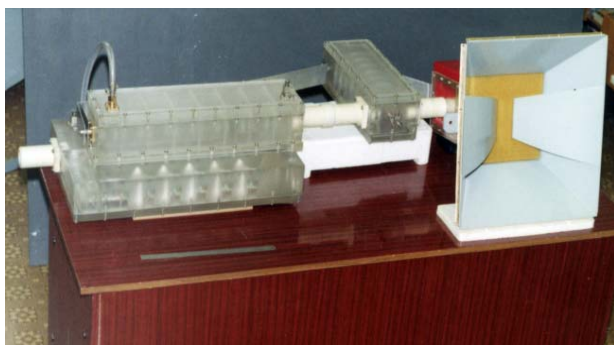
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14. ABSTRACT <b>Generation of broadband pulses with complex waveform and spectrum is of interest for numerous applications. These pulses can be formed by high-power generators with spectral bandwidths of ~0.5 GHz. Unlike ultra wideband (UWB) signal generators, broadband generators generate higher spectral power densities and have available effective antennas for transmission and receipt of these signals. The design of this generator was first described in [1] and is based on the direct driving of H-waveguides by gas-filled spark gaps. In this paper, the design of the dual spark-gap and of a mirror antenna with a customized broadband feed structure is presented. The dual spark-gap design includes a correcting capacitor. The designed shape of the mirror antenna provides high directivity of the transmitted radiation. In addition, the results of numerical simulations and experimental studies, targeting an increase in the operational efficiency and the radiated power levels of the generators, as well as the generation of radiation with the required spectra and waveforms, are presented.</b>			
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The spark-gap is filled with  $N_2$  or  $SF_6$  gas under pressures up to 18 atmospheres. The spark-gap is driven by a high-voltage capacitor store.

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



(a)



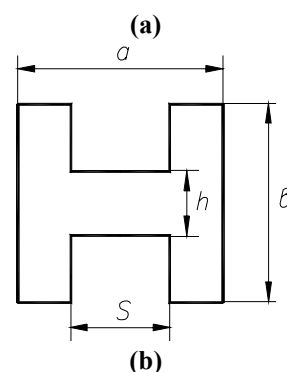
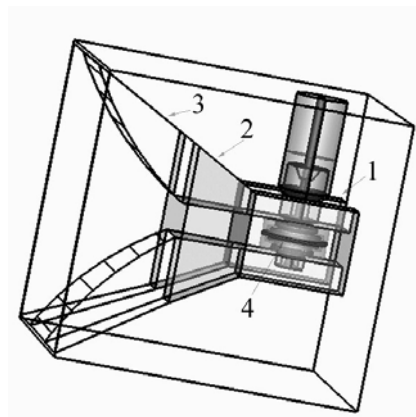
(b)

**Fig. 3.** Photo of H-waveguide generator with a dual spark-gap, driven by a Marx generator with intermediate capacitor store (a) and with dual pulse forming line driver (b).

Both generators utilized self-contained power supplies, based on a solid-state voltage up-converter, that operated at a repetition rate of 10Hz.

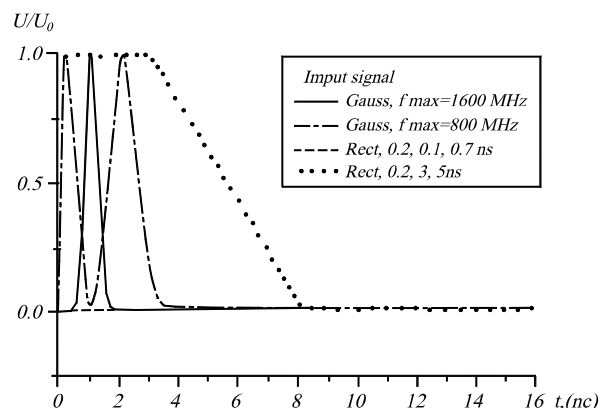
## II. COMPUTER SIMULATION RESULTS

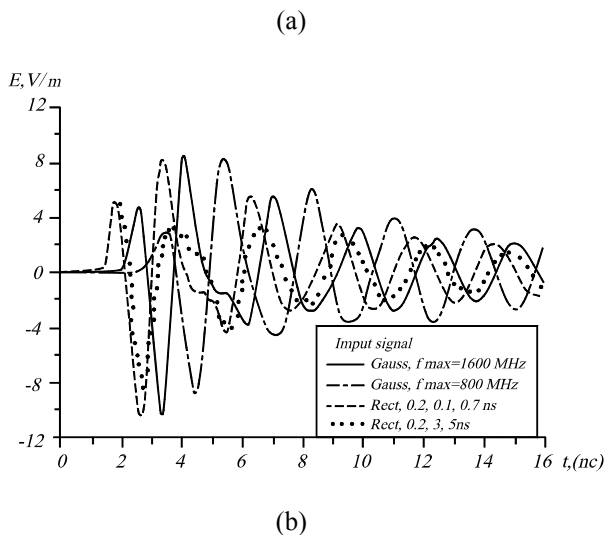
Computer simulations addressed the issue of matching the generator's electrodynamic structure (EDS) to the desired operating frequency band, which depends on certain parameters of the generator design and the driving pulse shape. A simulated design for the generator is shown in Fig. 4.



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

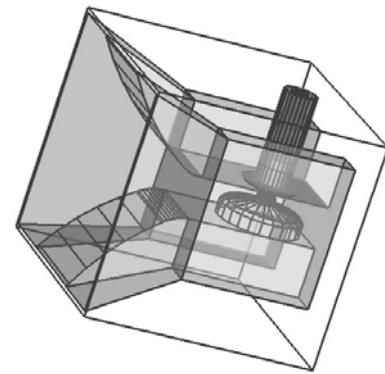
The simulated generator had the following H-waveguide dimensions:  $a = 180$  mm;  $b = 120$  mm;  $s = 80$  mm; and  $h = 50$  mm. The horn aperture size was  $450 \times 400$  mm. The internal waveguide cavity (excluding the spark-gap volume) is filled with purified transformer oil with permittivity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



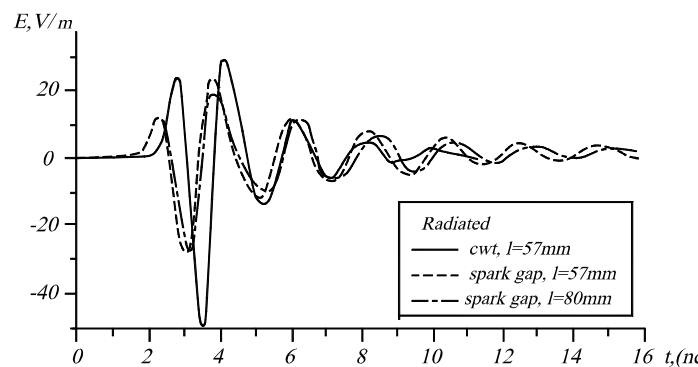


**Fig. 5.** Waveform of H-waveguide exciting pulses (a) and the E-component waveform for the radiated signal (b)

The data, shown in Fig. 5, corresponds to the excitation of the structure with 5-Ohm output impedance by a signal with unit power. It can be seen from the presented data that for short driving pulses, the form of the radiated signal is virtually independent of the driving pulse parameters. Two characteristic components can be isolated in the transmitted signal – basic bipolar signal and post-pulse oscillations. The 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, so the spark-gap impedance was not found. In view of this, the radiated signal amplitude was studied as a function of the driving spark gap impedance. Impedance values, close to realistic values, have been shown to provide efficiencies less than 10-15% for any spectral component of the driving signal transferred to the radiated signal. Optimizing the driving system showed that the most effective method for exciting the H-waveguide is to use a coaxial-waveguide transition of the special “button-like” type (hereinafter BCW) operating in the required frequency band. A schematic drawing of this structure is shown in Fig. 6(a). Results of computer simulations are presented in Fig. 6(b).



**Fig. 6 (a).** Computer simulation of H-waveguide excited by a “button-like” coaxial waveguide junction: 1 - broadband horn antenna of special shape; 2 - matching junction; 3 - H-waveguide; 4 - coaxial line; 5 - button-like electrode.

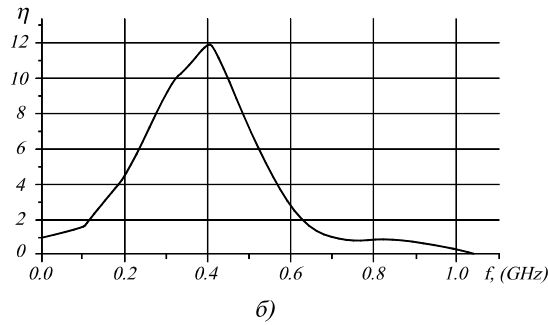
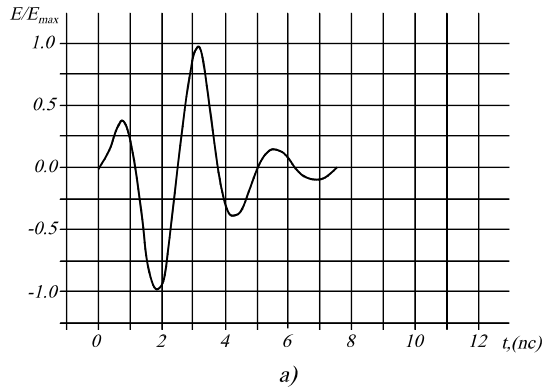


**Fig. 6 (b).** E-component waveform for the spark-gap and coaxial-waveguide junction excitations.

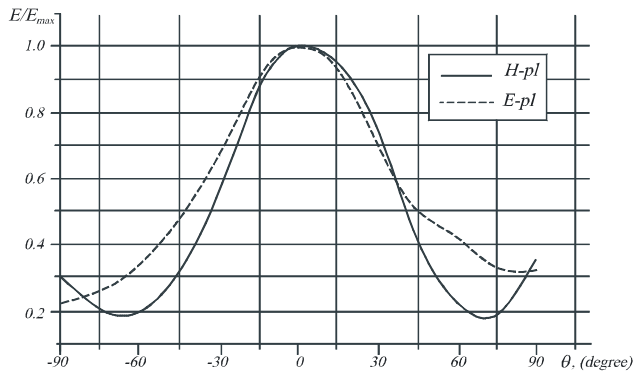
It can be seen from the presented data that when the H-waveguide is excited by a BCW, the amplitude of input signal is 1.8 times higher than that for the case where the spark gap is used to drive the H-waveguide. In this case, post-pulse oscillations, whose period is determined by the dispersion properties of the waveguide, diminish faster. Despite the higher efficiency, BCW excitation requires an effective pulse forming system. This requirement implies higher system weight and size. At the same time, a generator with direct excitation by a spark gap is simpler, more compact, and does not require dedicated pulse shaping device.

### III. Experimental results

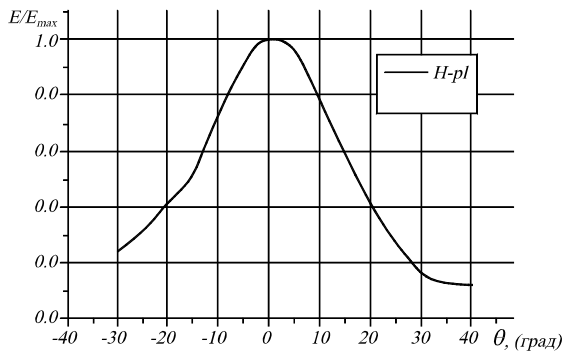
Several types of H-waveguide based generators have been tested. Basic characteristics of the H-waveguide unit were virtually identical with the excitation system being the main difference. Consequently, this led to certain differences in the output characteristics of the radiation. Figure 7 (a,b) displays typical experimentally measured waveforms and spectra of a tested generator. Figure 8 (a) shows the measured E and H planes beam patterns without reflector mirror. The beam pattern with reflector mirror and excentric feed position is shown at the Fig. 8 (b).



**Fig. 7 (a,b)** Typical experimentally measured waveform and spectrum of a generator.



**Fig. 8 (a).** Measured beam patterns in E and H planes without reflector



**Fig. 8 (b).** Beam pattern with reflector and excentric feed

Peak measured power in the generator is 400-450 MW when the amplitude of the driving pulse ranged up to 300kV. Further increase in the driving pulse magnitude leads to an increase in the

radiated power.

#### IV. Conclusion

The results of this effort confirmed that the H-waveguide horn structure shows good perspective for the forming and radiation of broadband pulsed signals with a spectrum bandwidth of  $\sim 0.5$ . Their advantages are that they are simple and compact, as well as it is feasible to implement effective directive antennas with low level side and back lobes. Experimental results qualitatively correspond to the simulation results.

#### V. References

V.A. Somov, Ya.N. Chepurnyy, Yu.V. Tkach, V.A. Kucherenko, "Non-Sine Impulse Waveform generator", *Electromagnetic Phenomena*, **2(5)**, Kharkiv (2001).