

The algorithm and program complex for splitting on a parts the records of acoustic waves recorded during the work of plasma actuator flush-mounted in the model plane nozzle with the purpose of analyzing their robust spectral and correlation characteristics

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Abstract. Currently acute problem of developing new technologies by reducing the noise of aircraft engines, including the directional impact on the noise on the basis of the interaction of plasma disturbances and sound generation pulsations. One of the devices built on this principle being developed in GPI RAS. They are plasma actuators (group of related to each other gaps, built on the perimeter of the nozzle) of various shapes and forms. In this paper an algorithm was developed which allows to separate impulses from the received experimental data, acquired during the work of plasma actuator flush-mounted in the model plane nozzle. The algorithm can be adjusted manually under a variety of situations (work of actuator in a nozzle with or without airflow, adjustment to different frequencies and pulse duration of the actuator). And program complex is developed on the basis of MatLab software, designed for building sustainable robust spectral and autocovariation functions of acoustic signals recorded during the experiments with the model of a nozzle with working actuator.

1. Introduction

Since the beginning of the 2000s active airflow control with help of plasma actuators began to gain more and more popularity. The main advantage of this process is that it directly converts electric energy into kinetic energy without involving moving mechanical parts. Thus it may be considered to be a very simple MEMS. Secondly, its response time is very short and enables a real-time control at high frequency. Its disadvantage is the low efficiency of energy conversion. Surface discharges may also modify the gas properties at the wall, such as density or viscosity [1].

Their own versions of plasma actuators of various configurations and shapes were designed by GPI RAS and named RING-1 and RING-2 [2]. These devices operate on the principle of sliding discharge and can be embedded on the perimeter of the nozzle.

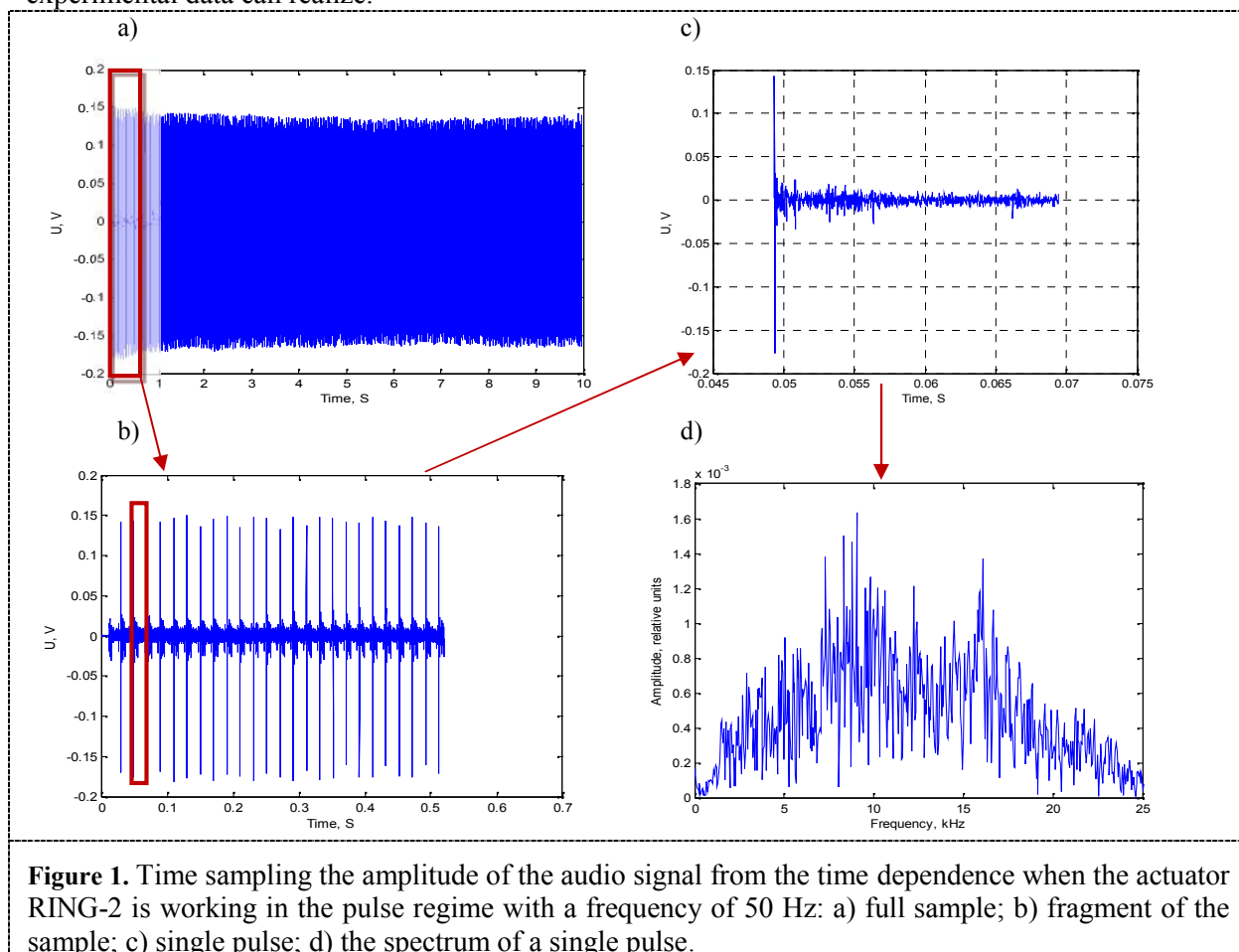
Multielectrode plasma actuators RING-1 and RING-2 works from special power supply generating sequence of HV-pulses with frequency up to 1 kHz. Study of acoustic waves characteristics generated by the nozzle as a result of actuator work is important, because they can reduce the noise of airflow issuing from the nozzle.

In this work the algorithm and program complex is presented that allows to analyze sound waves acquired during the work of plasma actuator flush-mounted at the end of the model plane nozzle with or without airflow. The developed algorithm allows to sort out compound parts from the received experimental data records (of different formats) - from one single pulse of all sampling frame of record to group of arbitrary number of pulses. And program complex (GUI) created on the base of MatLab software allows to build sustainable robust spectral and autocovariation functions of acoustic signals.



2. Experimental data information

Measurements of acoustic waves were performed with the help of professional audio equipment, so that the shock wave is not apparent in the signal from the microphone. At the distance of ~ 1.5 m at an angle 30 degrees to the axis of the nozzle microphone was mounted to record the acoustic characteristics of the system. From the microphone the electrical signal recorded and outputted spectral characteristics of the signal regardless of the type of experiment (with or without airflow through a nozzle) the output data structure receive that shown on figure 1 (a, b, c). Bursts of acoustic signal amplitude (figure 1 (a, b, c)) are associated with plasma discharges generated by the actuator. Figure 1 (b) is represented by the selection from the full recording a) and Figure 1 (c) shows a single pulse, that was single out from fragment of entry (b). Figure 1 (d) shows the spectrum of a single pulse of Figure 1 (c). The whole cycle of successive partitioning of the full sample entries into fragments and their subsequent processing demonstrates some of those features that program complex of experimental data can realize.



3. The algorithm for processing of the measurement information

Spectrum of signal built for the whole sample (Figure 1, a) is the sum of the two states, and provides no information about how behave acoustic waves generated by actuator inside the nozzle. To get an idea of what is going on inside the nozzle after one or a series of pulses of plasma actuator, it was decided to break whole the temporary realm of each sample recorded data on single pulses. For this purpose was developed a special algorithm and the program on the basis of MatLab software, allowing to investigate:

1. Dependencies signal or its fragment (single pulse) on time;

2. The spectra of the signal, or its fragment thereof, including robust spectra for the specified number of fragments (single pulse) of the original sample;
3. Autocovariance function signal or a its fragment (single pulse);
4. Depending on the time of two selected signals or their fragments (single pulses) on single coordinate axes;
5. Robust spectra of two selected signals or their fragments (single pulses) on single coordinate axes;
6. Autocovariance functions of two selected signals or their fragments (single pulses) on single coordinate axes.

The block diagrams of algorithm and the principle of the developed program are shown in Figure 2 and 3, and the appearance of software system in Figure 4.

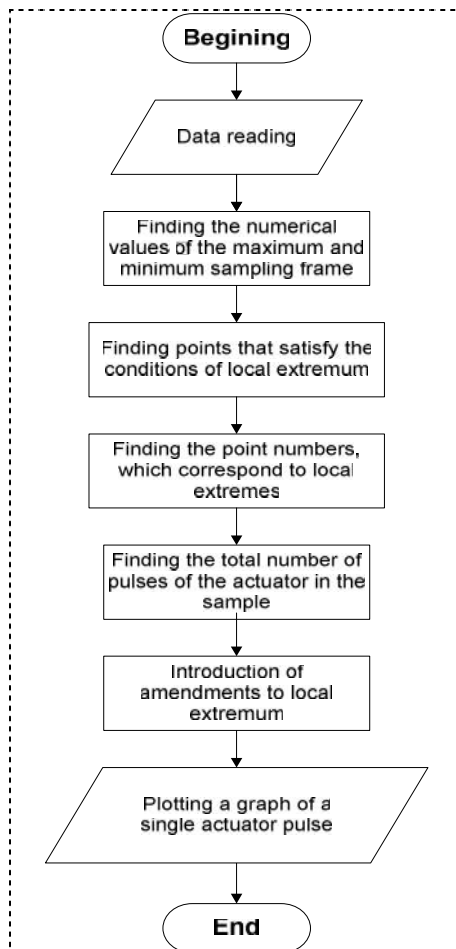


Figure 2. Block diagram of algorithm of experimental data partitioning on single pulses

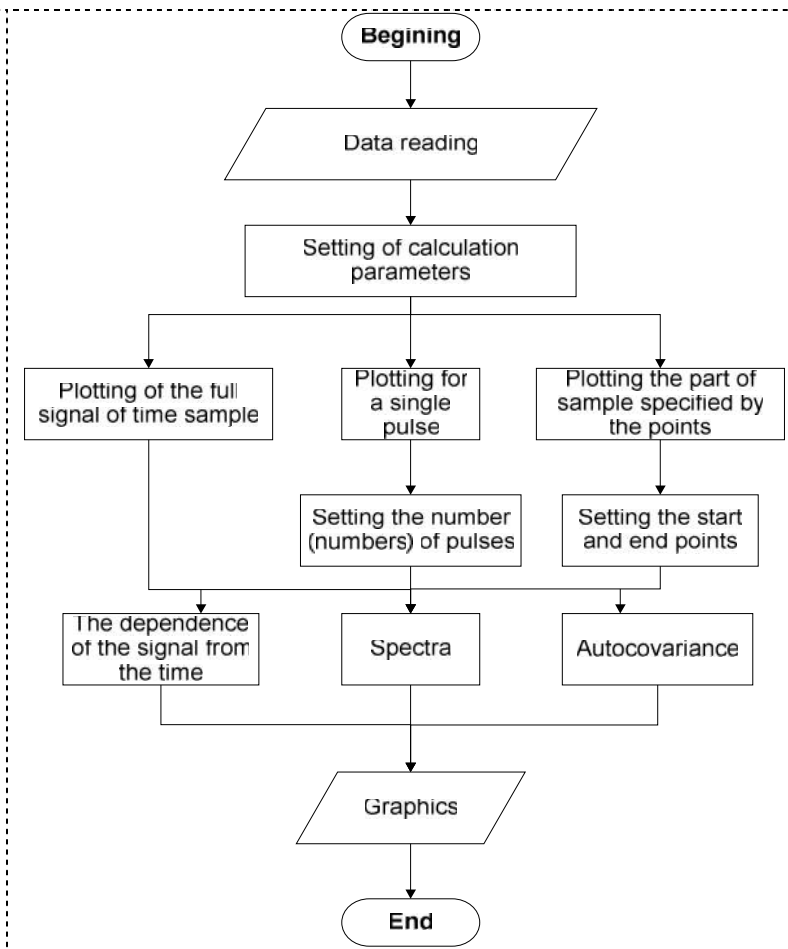


Figure 3. Block diagram of the order of work with data processing program complex

Reading the data and finding the numerical values of the maximum and minimum sample - executed by standard MatLab commands. After the data reading necessary to calculate the maximum and minimum of the whole sample, because their values will serve as a guide for finding the local extremes of single pulses. The most difficult part of the implementation of the algorithm is to find the sample points, which corresponds to local extremes, that are a sign of a new pulse. The principle of selection of points is shown in the block diagram (Figure 5).

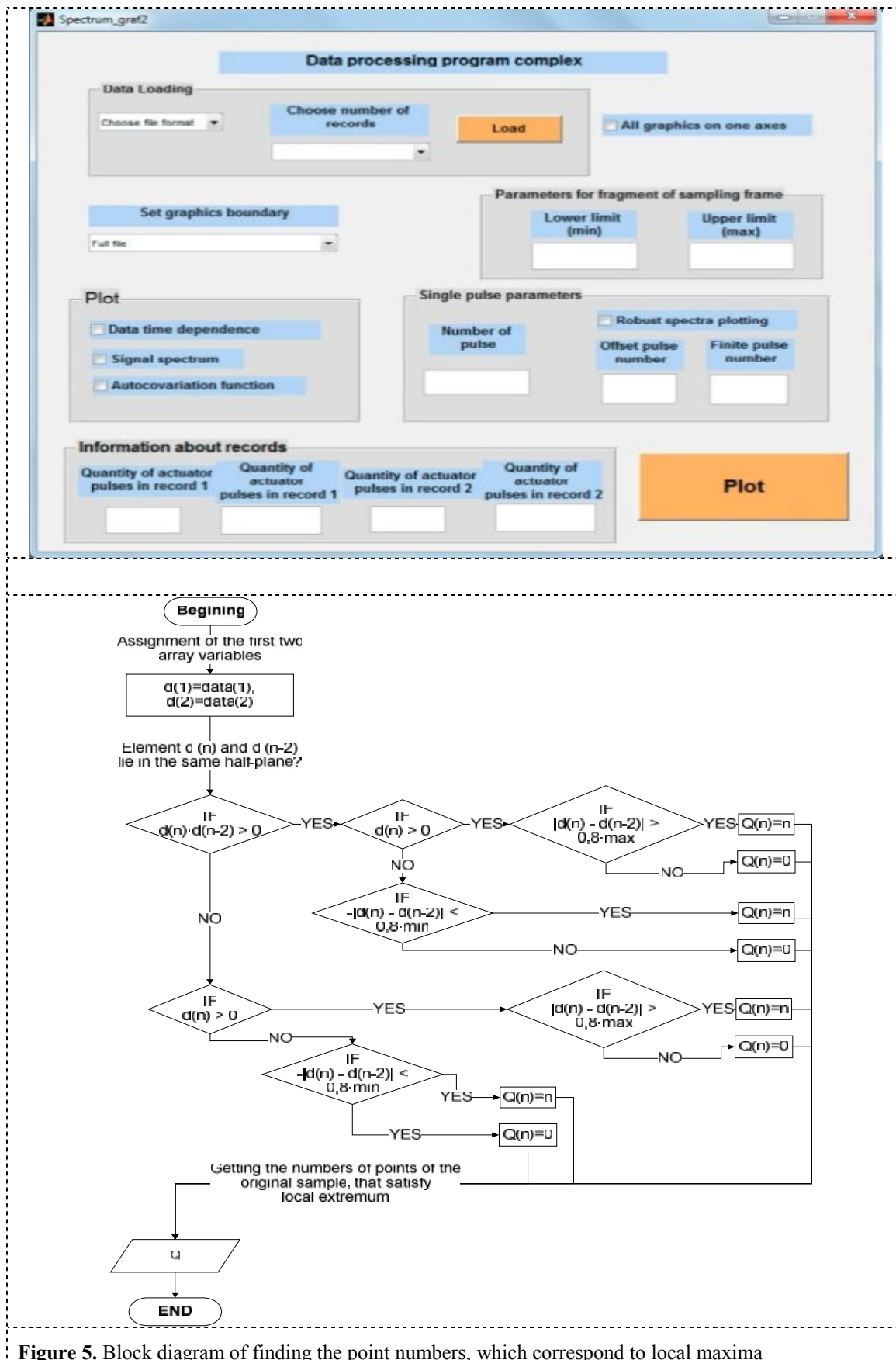


Figure 5. Block diagram of finding the point numbers, which correspond to local maxima

This scheme is for finding of points that satisfy a local maximum condition is selected because it is possible only 4 ways of occurrence pronounced extrema in the records of signals: 1) extreme point and precede to it a few points located in the upper half-plane (Figure 6, a), 2) extreme point and precede to it a few points located in the lower half-plane (Figure 6, b), 3) extreme point is in the upper half-plane, and precede to it a few points located in the lower half-plane (Figure 6, c), 4) extreme point is in the lower half-plane, and precede to it a few points located in the upper half-plane (Figure 6, d).

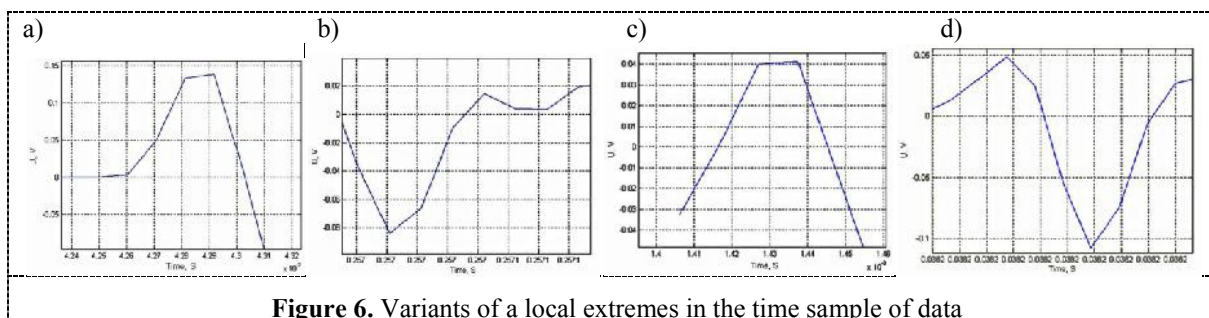


Figure 6. Variants of a local extremes in the time sample of data

Conditions of revealing the local maxima and minima are:

$$|d(n)-d(n-2)| > 0,8max \text{ and } -|d(n)-d(n-2)| > 0,8min, \quad (1)$$

where the max and min is the maximum and minimum value of the whole time sample signal, respectively, and $d(n)$ - the actual value of the signal in the time sample. These conditions were chosen as optimal for all of the measurements, as a result of viewing of all the databases of experiments and optimization solutions for finding local extrema of a single pulses. Next, from the data set, Q , which consists of zeros - numbers of points of sampling frame that not meet the above conditions and the values of points indexes of sampling frame that satisfy the conditions, with help of standard MatLab commands, zeros are removed. Of the remaining values of Q eliminated all values that are separated by 40 points from a local extreme. It is necessary to remove that values of local extremes, that satisfy the conditions (1), but not mean the beginning of pulse, because depending on the experimental conditions, the actuator pulses may have multiple sufficiently large extrema, we are interested in is the first one. Then the program calculates the total number of pulses found in the sampling frame. When constructing graphs from the extrema values is subtracted 5 points, this measure also identified by experiments database optimization and needed because the birth of the pulse happens before appearance of extreme.

4. Conclusions

Due to the sustained characteristics of robust spectra and autocovariance functions of the acoustic signals received with help of developed software it was found that the acoustic waves that are generated as a result of a plasma actuator RING-2, built-in nozzle model is done in two stages: 1) pulse actuator followed by reverb; 2) exit to the quasi-stationar comparable to the noise level.

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