

Acoustic Monitoring System of RF-Breakdowns Inside the Electrodynamical Structures at Kurchatov SR Source Accelerators

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Abstract

Monitoring and localization system of RF-breakdowns inside power supply waveguide and accelerating structure of electron linac - injector of SIBERIA storage ring is described. This problem had been solved by registration of ultrasound excited in electrodynamic structures metallic constructions by RF-breakdowns. The diagnostic system includes acoustic monitors displaced along the external surfaces of controlled structures. The RF-breakdown places are determined by signal delay times of these monitors. The experimental data handling and analyze are equipped with computer on-line.

1. Introduction

The electron linac - injector for the booster of the dedicated synchrotron radiation source SIBERIA storage ring was commissioned at RRC Kurchatov Institute [1]. The linac consists of klystron amplifier, which generates 8 msec pulses at 2.8 GHz, and accelerating disk-and-washer structure [2]. The klystron and accelerating structure are connected by the rectangular waveguide, whose length is equal to 12.5 m and cross-section is $90 \times 45 \text{ mm}^2$. This waveguide is divided by ceramic window into two parts, first one (adjacent to klystron) is filled with nitrogen at 6 atm and second one is under vacuum. Now the klystron operates at 6 MW RF-power, it provides 70 MeV accelerated beam. The monitoring system based on acoustic sensors, which define the initiation time and the location of RF-breakdowns place inside power supply waveguide and accelerating structure was created. It is important to operate at high power level and to trainee of the linac structure.

2. The acoustic monitoring for the electrodynamic structures

A new checking method of operating conditions for the electrodynamic structures was advanced in RRC Kurchatov Institute and first used at linac FAKEL [3]. This method based on registration of the acoustic ultrasound perturbation excited in metallic walls of structure by pulsed RF-field [4]. The mechanisms of ultrasound perturbation are ponderomotive and thermoelastic (the non-stationary heat

evolution). The acoustic methods are attractive by following features: first, the processes study at high power level, second, acoustic methods are not demand the location of monitors inside closed electrodynamic structures, third, these methods protect against interference, that is acoustic signal accept in tens or hundreds microseconds after electromagnetic pulse.

The non-stationary heat evolution in breakdown region is a reason of the acoustic effect of RF-breakdown. The pulsed RF-field causes pulsed acoustic perturbation of metallic constructions. The pulse of acoustic excitation propagates along whole metallic constructions of the electrodynamic structure and accepts by the external acoustic monitors. The propagation time of acoustic perturbation front determines a distance from the breakdown region to the point of monitor location. The wave front of acoustic perturbation, passing through metallic constructions of unhomogeneous structures, distorts because the perturbation propagates by different types of acoustic waves and in wide frequency range. To increase an accuracy of measurements, a frequency bandpass of a line from acoustic monitor to amplifier can be optimized. Because the RF-breakdown duration lies in range between 1 and 10 msec, the acoustic perturbation spectrum is in ultrasonic frequency zone, that is below 1 MHz. To increase the distortions of the wave front, which exist because of geometric dispersion and dispersion on resonance unhomogeneity, one can make the upper bound of the bandpass 800 - 1000 kHz.

Along the external surface of waveguide and linac structure are located the acoustic monitors, whose signals are transmitted to an entrance of a 4-channels digital oscilloscope, connected with computer, these signals are shown on the oscilloscope screen.

The acoustic monitor consists of a sound-transmitter, a sensor and an amplifier. The sound-transmitter is made due to delay the acoustic signal propagation in 50 msec to sensor. The sensor of monitor (electroacoustic converter) is ceramic pellet. This ceramic has high sensitiveness and rather low quality factor of pellet's natural oscillation. The amplifier with factor 60 dB is used due to increase a signal-noise ratio. The monitor bandpass lies in the range between 50 and 800 kHz, the monitor sensitiveness provides the registration of acoustic tension in structures' walls near 10 N/m^2 .

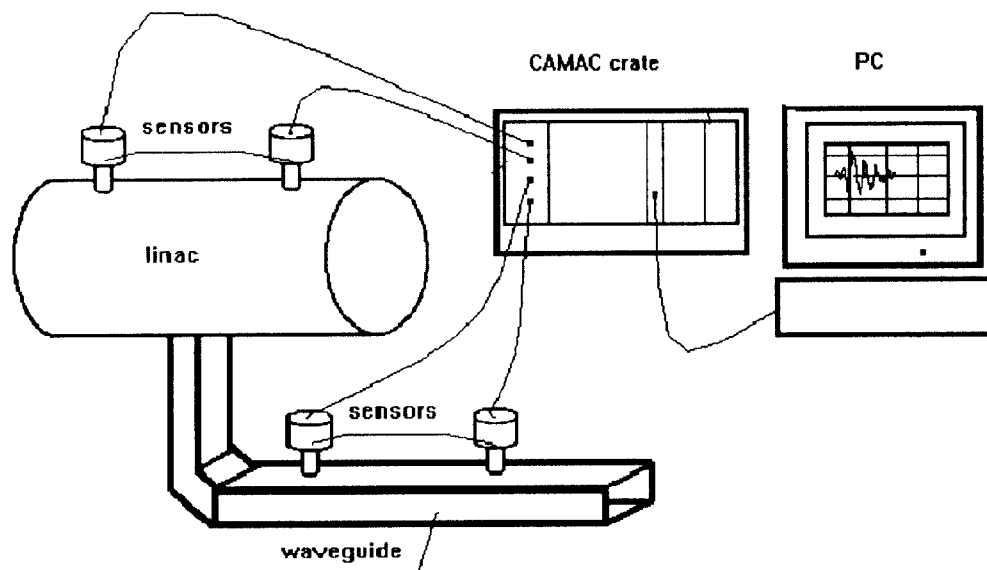


Fig.1. Scheme of monitoring and analysis of the signals.

Scheme of measurements is shown in Fig.1. The standardized CAMAC modules were chosen for data handling and representation : a microcomputer, an analog-digital converter (ADC), PC-interface. The ADC module is a transient recorder, which provides maximum working rate of 20 MHz, 8 bit resolution and 1024 words of an operational memory [5].

The signal, recorded by sensor, is result of superposition of ultrasonic waves, which excited by RF-breakdowns and multiple reflected inside the walls of electrodynamic structures. By pulse simulated the acoustic effect of RF-breakdown, one can measure the wave propagation velocity. For the waveguide it is equal to 2500 m/sec. The without breakdown signal is shown in Fig.2, its delay time is equal to 50 msec. An amplitude of signal is linear with RF-power. The breakdown signal is a one order more and simply identified in comparison with normal signal. Its delay time is defined by a distance between the breakdown region and the location point of the monitor. For example (see Fig.3) this time is equal to 300 msec, it corresponds to 0.75 m along waveguide.

3. Acoustic Monitoring System of RF-Breakdowns.

The accuracy of determination of distance between the monitor and breakdown region is defined by uncertainties of breakdown initiation moment and propagation velocity of acoustic perturbation front. The uncertainty of breakdown initiation moment is limited by RF-pulse duration, for example 10 msec pulse corresponds to 5 cm long error. However an influence of these errors may be

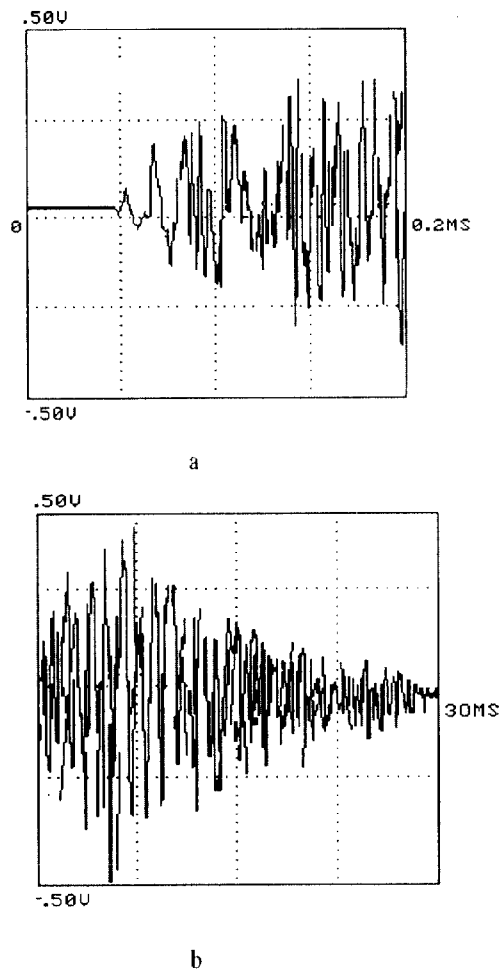


Fig.2. The oscillogram of acoustic sensor signal, a) and b) correspond to different time scale.

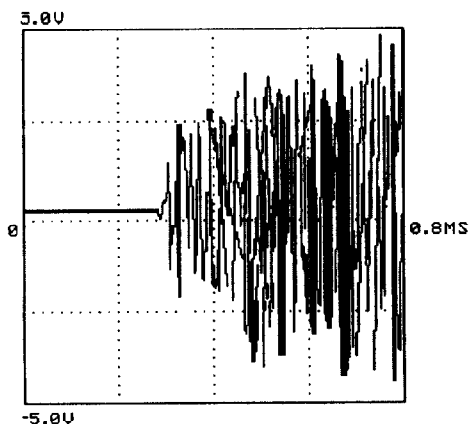


Fig.3. The oscillogram of breakdown signal.

except, if use three monitors located along the electrodynamic structure. The Fig.4 shown the screen copy of the multichannel digital oscilloscope. The monitoring system consists of three sensors, located on external surface of linac structure : first one in the beginning of structure (upper curve), second one in the middle, and third one near to the power input (down curve). The handling of results allows to control breakdown on real time. For example Fig.4a and Fig.4b shown some drastic increase in two sensor's signals, the delay time of first breakdown signal is equal to 450 msec, and second one 700 msec. Using the calculated data as the base, one can define the breakdown region exists in 0.4 m from beginning of linac structure. In the similar way Fig.4c shown breakdown inside the power input section.

4. Summary.

Acoustic monitoring system of RF-breakdowns inside the electrodynamic structures allows to fix breakdown on real time and with accuracy of 1 cm. The progress is associated with spectrum analysis of acoustic perturbation signal, in this way the elements of structure, where breakdown is initiated, are discovered. In finally, modified system will allowed to calculate main electrodynamic parameters of disk-and-washer accelerating structure at high RF-power, as well as to control accelerating modes of linac. It should be noted that these acoustic methods can be used for both other electron linac and heavy ion linac structures.

5. References.

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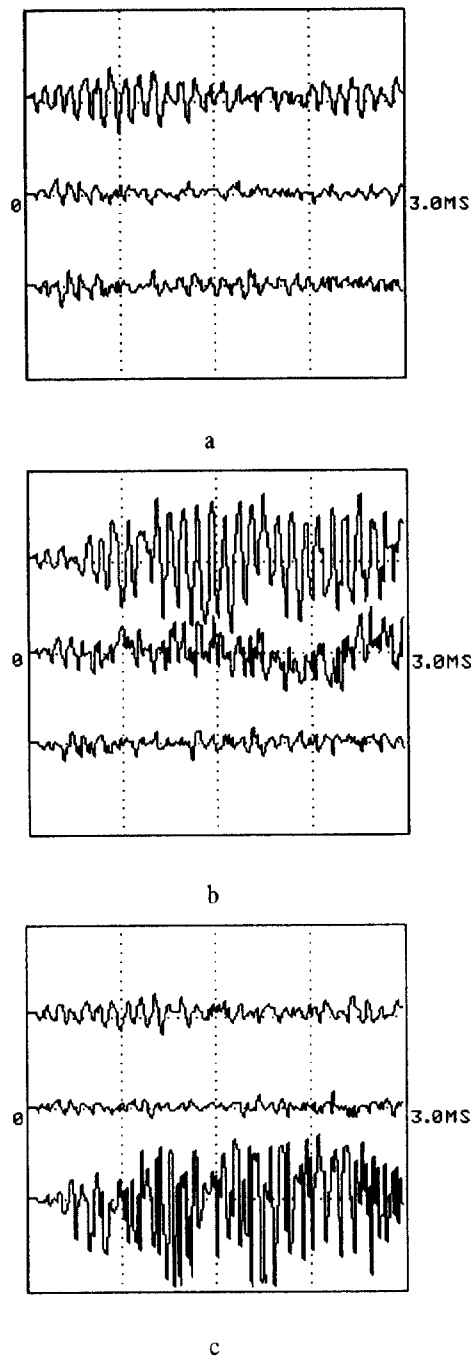


Fig.4. The oscilloscope's screen copy for three sensors along linac; a) without breakdown, b) and c) breakdown inside accelerating structure.