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STUDY OF THE ACOUSTIC PICTURE OF KLYSTRONS AND MODULATORS OF THE LU10 ACCELERATOR DURING RADIATION IRRADIATION OF A SUPERCRITICAL WATER LOOP

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Currently, there is an urgent problem of diagnosing the operation of klystrons and accelerator modulators for prompt response to possible emergency situations. According to the obtained data, the normal and emergency mode of operation of the equipment differ quite significantly in terms of the acoustic picture. Since there is a certain volume of acoustic information on the operation of the LU10 accelerator, a decision was made to investigate the cases of emergency and regular versions of the equipment operation.

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INTRODUCTION

When conducting acoustic diagnostics of processes in a convection supercritical water loop (SCWL) under electron irradiation [1], it became necessary to isolate noises introduced by the operation of the accelerator systems (LEA).

Research was conducted on the basis of statistical data of 600 hours of SCWL work session. Acoustic fragments of moments of disconnection and subsequent inclusion of LEA klystron modulators during the SCWL irradiation session were investigated.

1. GENERAL DESCRIPTION OF THE DEVICE

The decision was made to choose STM32F4-Discovery as the basis for the device, since the microcontroller on this board has a sufficient amount of memory, a sufficient operating frequency (168 MHz), supports the RMII interface, which allows the use of Ethernet network adapters, and is equipped with a 12-bit ADC, which allows you to distinguish the signal level with an accuracy of up to 8 mV. The next step was the selection of an acoustic module: MAX9814 has proven itself as a high-quality acoustic module, distinguished by ease of connection and quality of sound wave transmission. The DP83848 module was chosen to work with the Ethernet network. The power source is a mobile phone charger that supplies 5 V and 1 A current output.

As a server, you need a computer with the following minimum possible characteristics:

- OS: Windows 7 Professional x64, or Windows 10 Professional x64;
- CPU: dual-core, 2.8 GHz or better;
- RAM: DDR3 8 GB or better.

The following schematics were used to connect the modules:modules:

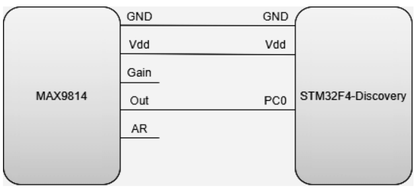

Fig. 1. Schematic diagram of the MK connection with the microphone module

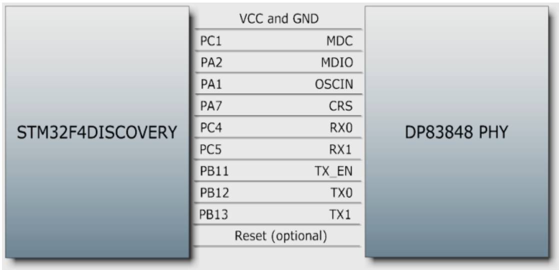

Fig. 2. Schematic diagram of the MK connection with the Ethernet interface module

2. CHARACTERISTICS OF THE MODULES

Acoustic module MAX9814:

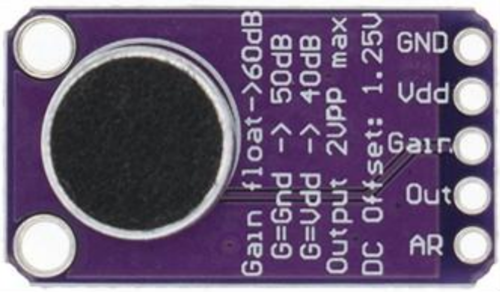

Fig. 3. MAX9814

This module is responsible for converting acoustic waves into electromagnetic waves and has the following characteristics:

- Supply voltage: 2.7…5.5 V at a current of 3 mA;
- Output: 2Vpp at 1.25 V offset;
- Frequency response: 20 Hz…20 kHz;
- Programmable attack and decay ratio;
- Temperature range -40...+85 °C.

Ethernet network adapter module DP83848:

Fig. 4. DP83848

This module is designed for communication of a microcontroller module with an Ethernet network, has the following characteristics:

- Network support: 10 / 100 Mbit;
- Standard: 802.3u MII/RMII;
- Supply voltage: 3.3 V;
- Power consumption: <270 mW.

Microcontroller module STM32F4-Discovery:

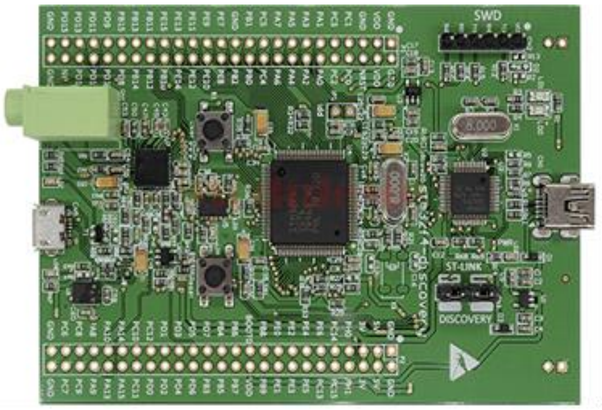

Fig. 5. STM32F4-Discovery

This module is responsible for receiving an analog signal, converting it to a digital one, accumulating data and transferring it to the server application via the Ethernet network. The maximum clock frequency is 168 MHz, the polling frequency of the ADC is 32768 Hz. The supply voltage is 5 V at a current of 300 mA.

3. SOFTWARE

In addition to the firmware files for the MK, software for exchanging, storing and processing information of the following architecture was also used:

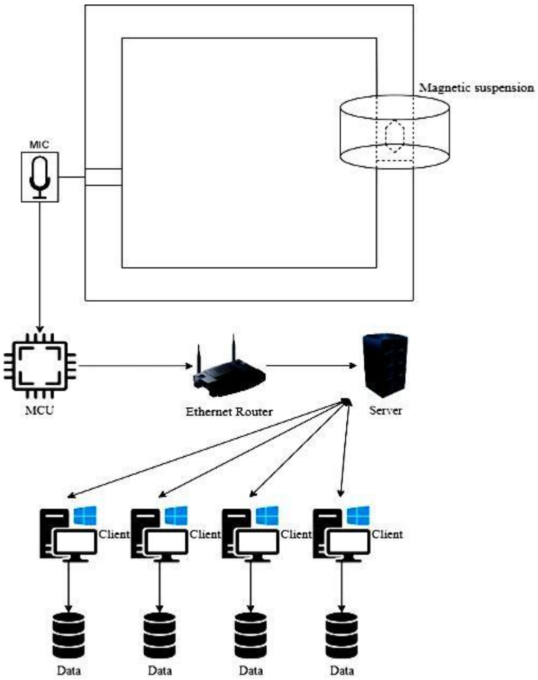

Fig. 6. Network architecture

The pre-developed Spectrum application was used for information exchange ! TCP Server:

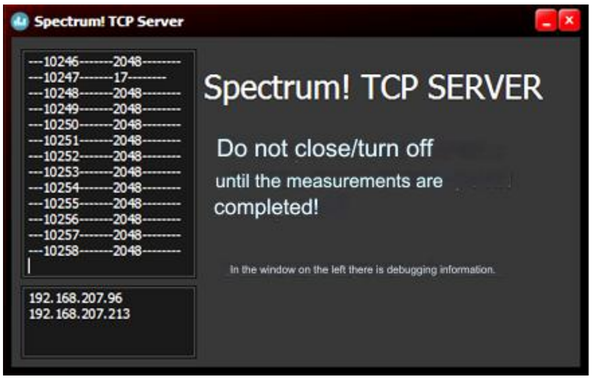

Fig. 7. The Spectrum! TCP Server

Spectrum! application was used for visual control of operational data and information storage:

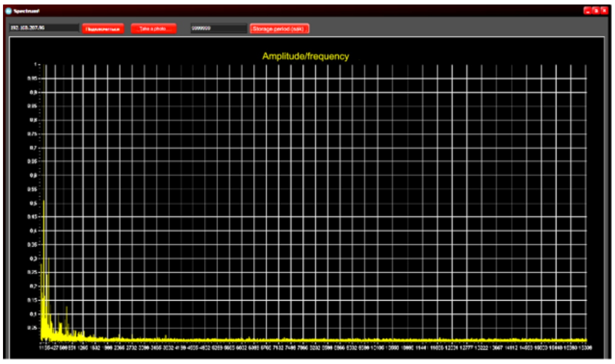

Fig. 8. The Spectrum App!

Spectrum application was additionally modified and improved for playback and processing of saved data ! ReMember:

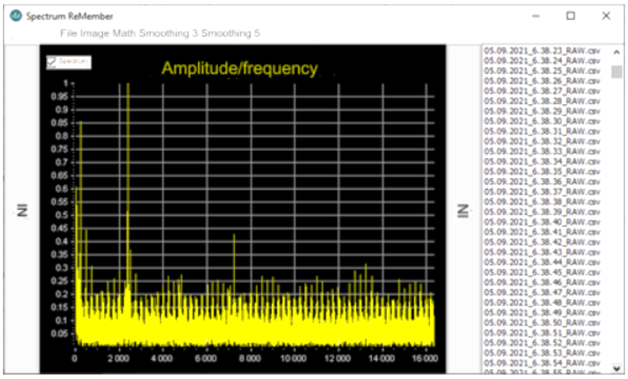

Fig. 9. App Spectrum! ReMember

Thus, the software developed and improved according to needs from the software complex for acoustic diagnostics was used to conduct the research.

5. RESEARCH RESULTS

According to the recording conditions, the sound-recording sensor was partially activated isolated from external influence, therefore, in order to find the necessary information, it was necessary to conduct a study of data arrays subject to additional processing by filtering methods, since the received records have a high level of white noise contamination, and the useful signal (from modulators and klystrons) does not have sufficient amplitude to be distinguished by the unarmed eye. Thus, to search for regularities and calculations, the following were applied:

- Smoothing filters with a window of 3 and 5 steps;
- Running average smoothing filter;
- Averaging the spectral component over time: comparing the average spectrum over time when the accelerator systems are clearly in their normal state and finding intervals when the accelerator systems were already turned off, and the process of phase transition (boiling) has not yet begun in the SCWL, as this process is accompanied by powerful white noise , which makes any spectrum studies impossible.

As a result of research, the following data have been obtained so far:

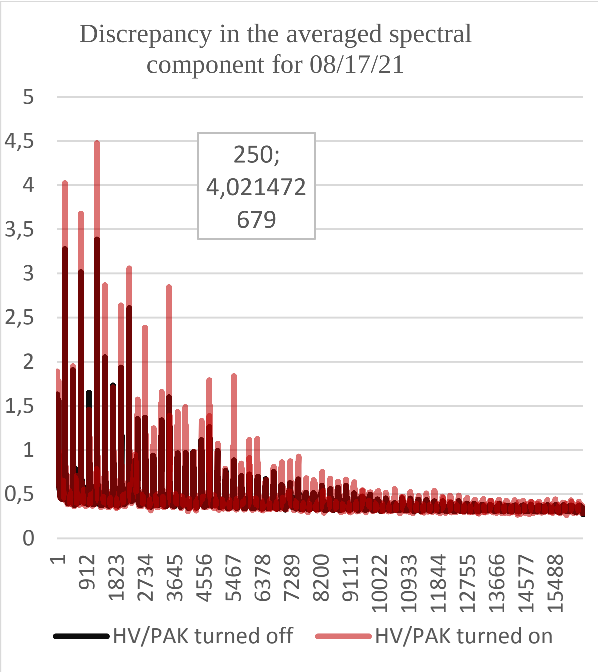

Fig. 10. Graph of the discrepancy in the averaged spectral component for 08/17/21

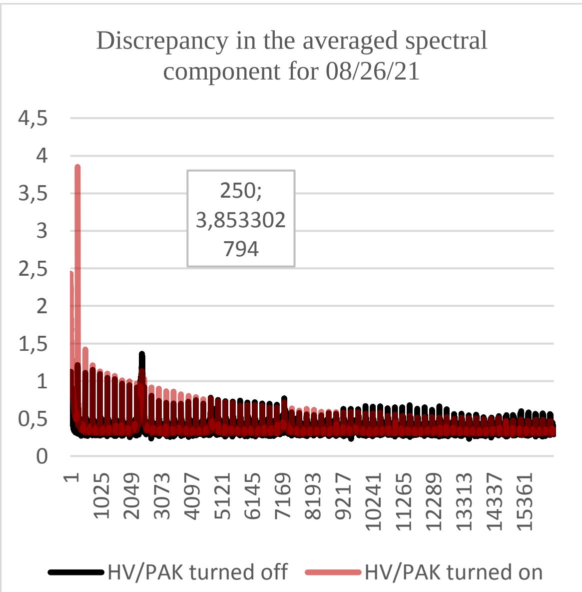

Fig. 11. Graph of the discrepancy in the averaged spectral component for 08/26/21

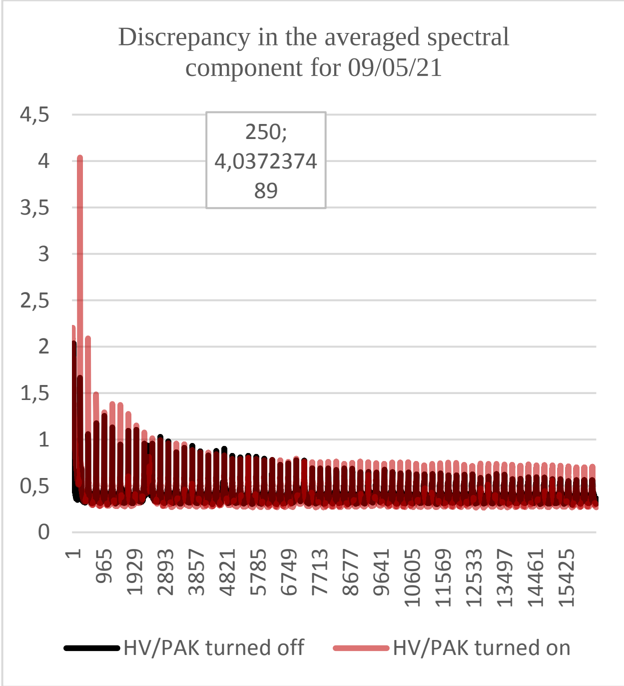

Fig. 12. Graph of the discrepancy in the averaged spectral component for 09/05/21

CONCLUSIONS

Thus, as can be seen from the graphs, the main frequency change in emergency situations falls on the frequency of 250 Hz and its harmonics (500, 750, 1000 Hz).

There are also certain changes in the low-frequency component (up to 250 Hz), but within the existing data arrays, there is currently no clear picture of the dependence of the change in the acoustic picture in this range on the state of the devices.

Currently, there are plans to investigate the operation of modulators and klystrons without additional acoustic insulation in more detail with the help of the existing complex of acoustic diagnostics for a more detailed study of the acoustic picture of their operation in order to implement operational control of their functioning.

REFERENCES

1. O.S. Bakai, V.M. Boriskin, V.V. Churikov. Acoustic diagnostics of coolant phase transitions in a supercritical convection water loop // *Problems of Atomic Science and Technology. Series "Nuclear Physics Investigations".* 2023, N 6 (148), p. 161-167.

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ДОСЛІДЖЕННЯ АКУСТИЧНОЇ КАРТИНИ РОБОТИ КЛІСТРОНІВ ТА МОДУЛЯТОРІВ ПРИСКОРЮВАЧА ЛУ10 ПРИ РАДІАЦІЙНОМУ ОПРОМІНЕННІ НАДКРИТИЧНОЇ ВОДНОЇ ПЕТЛІ

В.М. Борискін, В.В. Чуріков

При проведенні акустичної діагностики процесів у конвекційній надкритичній водній петлі (КНВП) під опроміненням електронами виникла необхідність виділення шумів, що вносяться роботою систем прискорювача (ЛПЕ). Дослідження проводилися на підставі статистичних даних 600 год сеансу роботи КНВП. Було досліджено акустичні фрагменти моментів відключення та подальшого включення модуляторів клістронів ЛПЕ під час сеансу опромінення КНВП.