ABSTRACT

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"DEVELOPMENT OF METHODS AND INFOCOMMUNICATION SYSTEM FOR SEARCHING RESPONSE EARTHQUAKE PRECURSOR BASED ON INTELLIGENT ANALYSIS OF SEISMOGRAMS"

thesis,
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specialty: 6D071800 - "Radio Engineering, Electronics and Telecommunications"

The research topicality.

Currently, the use of radio-electronic and info-communication technologies and applied computer programs make it possible to formulate new scientific approaches and innovative solutions in almost all basic research, contributing to the safety of the population.

Seismology, at the intersection of geological and physical sciences, in a theoretical aspect studies the causes, essence and patterns of earthquake propagation, and in applied - generates knowledge to protect against earthquakes by predicting and reducing injuries for the population and the destruction of structures. Seismology is closely related to seismometry, which is engaged in the development of methods and instruments for recording seismic waves.

In the Republic of Kazakhstan, an earthquake is an urgent problem due to the presence in the zone of increased seismic risk with a high frequency, for example, in Almaty and Almaty region, up to 400 earthquakes are recorded every year. The urgency of the problem of seismic activity is growing, since the west and the center of the country have also entered the risk zone, since tremors began to reach magnitudes of more than 6 points there.

In almost every country, scientific teams are engaged in earthquake prediction research, however, this issue has not been effectively resolved yet and continues to be relevant. Prediction of earthquakes is based on the identification of their precursors, in particular, seismic, geophysical, geochemical, hydrodynamic, etc. But their use remains insufficiently effective due to low information content and stability.

At the same time, it was established that all earthquakes precursors, including in the form of foreshocks, changes in deformations and inclinations of the earth's surface, travel speeds of longitudinal and transverse seismic waves, changes in water level underground, dynamic compression of rocks, lead to changes in the shape of seismograms. Therefore, by conducting a deep analysis of seismological signals, based on intelligent methods, it is possible to efficiently and qualitatively recognize and identify the earthquakes precursors. Since noise signals are certain manifestations

of fracture preparation processes, their study is interesting enough to predict earthquakes.

Over the past five years, in connection with the rapid development of info-communication and computer technologies, technologies based on the application of digital processing methods for radio engineering signals have become a very effective and promising area for the analysis of seismograms: neural network technologies, wavelet analysis, analytical and numerical modeling, theories of fuzzy sets etc. In this direction, the researchers obtained serious results on the establishment of patterns in changes in the parameters of seismograms for the earthquake prediction, but it is necessary to conduct a number of studies to determine the earthquakes precursors and evaluate their effectiveness, and determine the time intervals.

The collection and analysis of the seismological situation in the Republic of Kazakhstan is carried out using the seismological monitoring system, which is one of the best in Central Asia and covers the southern and southeastern regions. It includes observation networks: seismological, geophysical, hydro-geological, biological, and for modern movements of the earth's surface. Each network transmits information via telecommunication channels to the center for the collection, processing and storage of information.

To ensure an effective assessment of seismological activity throughout Kazakhstan, the system modernization is required by increasing the coverage of the observation area with the inclusion of central and western regions, creating high-speed and low-cost information transmission channels based on modern radio electronics and wireless technologies, including data on earthquake precursors.

The research aim is the research and development of an info-communication system using intelligent methods and algorithms for collecting and processing seismograms with the search for response earthquake precursors based on modern radio and wireless technologies to improve forecasting efficiency.

The Research Objectives:

- analysis of problems in seismology for earthquake prediction and the functioning of surveillance networks of a seismological monitoring system;

- development and research of effective and universal methods and algorithms for analyzing and processing digital seismic signals to search for response earthquakes precursors based on identification measurements of shape parameters and virtual frequency of seismogram characteristics;

- development of computer devices based on the search methods for response earthquake precursors and their testing on the basis of the Laboratory of Comprehensive Earthquake Prediction, "Institute of Seismology" LLC of the Ministry of Education and Science of the Republic of Kazakhstan;

- conducting experimental studies to determine response earthquakes precursors based on the analysis of real seismograms;

- development of a set of technical solutions for recommendations on the modernization of a seismological observation network based on the use of LTE

wireless technologies and Wi-Fi radio bridges to ensure economic efficiency and improve quality parameters;

- development of the structure of the info-communication search system for response earthquake precursors.

The research object is the radio engineering methods of digital processing and intelligent analysis of seismic signals and info-communication equipment of monitoring networks of seismological monitoring systems.

The research subject is the processes of extracting information about earthquake precursors based on the intellectual analysis of seismograms during monitoring, the modernization of data transmission channels in a network of seismological observations.

The research methods.

Radio engineering methods of digital signal processing of random signals, spectral and wavelet analysis, intelligent identification and recognition, tools for mathematical modeling of linear algebra and statistical radio engineering are applied to solve the objectives in the thesis.

Computer modeling and automation of mathematical calculations were actively used in the course of experimental research.

Modernization of data transmission channels of the seismological observation network was carried out using the technology of designing radio engineering systems and on the basis of a modern database of electronic components.

The scientific novelty of the thesis consists in the following provisions and results.

- A general approach has been formed to the automated search for response earthquake precursors to determine informative features based on the formation of discrete identification characteristics with simultaneous comparison with threshold values.

- A method is proposed for searching for "minute" and "second" response earthquake precursors, characterized in that the processing of complex seismic signals is based on vector identification measurements of the temporal characteristics of the seismogram and its increments, and the search for response earthquake precursors is carried out by the threshold value of the shape parameter.

- A method is proposed for searching for "clockwise" response earthquake precursors, characterized in that the processing of complex seismic signals is based on vector identification measurements of the temporal characteristics of the seismogram and its increments, and the search for operational earthquake precursors is implemented using threshold heterogeneous parameters of shape and virtual frequency.

- A methodology and algorithm for digital processing of seismograms and an integrated search for response earthquake precursors have been developed, characterized in that the "second", "minute" and "hour" response earthquake

precursors with a probabilistic assessment of earthquake prediction are used in seismic monitoring.

- A methodology and algorithm for the digital processing of seismograms and the search for response earthquake precursors have been developed, characterized in that the "minute", "second" and "hour" response earthquake precursors are determined sequentially independently of each other during seismic observation.

- A set of technological solutions is proposed for the development of computer devices for the intellectual analysis of seismograms with the search for earthquake precursors, for the modernization and construction of information transmission channels for all observation networks based on the use of Wi-Fi radio bridges and LTE technology.

The practical significance.

The proposed methods and algorithms for digital processing of seismograms and the search for response earthquake precursors by the shape and virtual frequency parameters of the seismogram characteristics are a practical basis for designing compact and universal tools for predicting emergencies and natural and man-made disasters with the automatic issuance of expert estimates, quantitative parameters and linguistic descriptions to the user in terms specific to this subject area and accepted by experts.

The developed computer device allows searching for response earthquake precursors, is built into the network of seismological observations, providing guidance to the operator on prediction time directly at the Information Collection and Storage Center or the Central Seismic Observatory of Almaty, and also helps to replenish the database of response earthquake precursors.

An info-communication system for searching for response earthquake precursors is proposed, including a developed computer device and wireless data transmission channels based on Wi-Fi radio bridges and LTE technology, integrated into seismological observation networks and providing high-speed information transmission over long distances.

Relationship with government programs.

The scientific studies presented in the thesis were carried out in the framework of grant funding of the Ministry of Education and Science of the Republic of Kazakhstan on the issues: "Development of computer devices and software and hardware systems based on the theory of identification measurements and transformations of information signals and processes for solving measurement, control, diagnostics, testing and Management "(0196 / GF state registration number) and "Development of intelligent computer devices and diagnostics and monitoring systems for oil and gas equipment "(2605 / GF4-15-OD state registration number).

Thesis provisions to be defended (research results):

- An approach to digital processing of seismograms based on vector measurements of shape parameters and virtual frequency of identification characteristics.

- Search methods for response earthquake precursors based on vector identification measurements of temporal characteristics of a seismogram and their increments and comparison with threshold values of shape parameters and virtual frequency.

- Methods and algorithms for digital processing of seismograms with a comprehensive search for response earthquake precursors.

- Structures of computer devices for searching for response earthquake precursors.

- Seismological observation network structure with a computer device for searching for response earthquake precursors and data transmission channels based on Wi-Fi radio bridges and LTE technology.

The approbation of results. The main results of the dissertation research were presented and discussed at the International conferences "International Conference on Applied Mathematics, Modeling and Simulation" (AMMS, Shanghai, China, 2017) and "11th International Conference on Computer Science and Information Technologies" (CSIT, Yerevan, Armenia, 2017); International scientific and practical conferences "Technical sciences: problems and solutions" (Internauka, Moscow, Russia, 2018), "Problems of developing technical potential and ways to increase it" (Sterlitamak, Russia, 2019) and "Kozybaev readings - 2018: Eurasian potential and new development opportunities in the face of global challenges "(Petropavlovsk, Kazakhstan, 2018).

Publications. The main results of the thesis research were reflected in 21 scientific papers, including in two patents of the Republic of Kazakhstan, 5 articles in publications recommended by the Committee for Control in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, 3 articles in international scientific journals with a non-zero impact factor according to Journal Citation Reports of Clarivate Analytics and Scopus, 8 works reflected in proceedings of international scientific conferences, including two conferences in the Journal Citation Reports database of Clarivate Analytics and Scopus.

The personal contribution of the author.

The main results of theoretical and experimental studies were independently obtained by the author. In printed works that are written in collaboration, the doctoral student has a leading role in the synthesis and analysis of the results.

The structure of the thesis.

The thesis consists of introduction, the main part, including four parts, conclusions, bibliography of literature cited and three appendices. The thesis is presented on 124 pages of computer text, includes 51 figures, 13 tables and 124 titles of bibliography of literature cited.

The first part of the thesis gives the basic concepts of the development direction used in seismology, presents the results of the analysis of the current situation, the prerequisites for the search for earthquake precursors.

The second part of the thesis describes a search technique for response earthquake precursors, presents a mathematical model for describing the temporal characteristics of seismograms, and develops the structure of an intelligent computer device of a combined search technique for response earthquake precursors.

The third part of the thesis presents experimental studies of the search for response earthquake precursors, based on identification methods (S-method and FRaSH method), two measuring channels of a computer device were developed, two methods were proposed for searching for response earthquake precursors, and their algorithms are presented in the form of circuits.

In the fourth part of the thesis, engineering solutions are developed for the modernization of data transmission channels using modern wireless info-communication technologies, such as LTE and Wi-Fi radio bridges, which provide high-speed transmission of information in seismological observation networks.