28 FEBRUARY 1979 (FOUO 12/79) 1 OF 3

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PHYSICAL SCIENCES AND TECHNOLOGY
(FOUO 12/79)

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TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY
PHYSICAL SCIENCES AND TECHNOLOGY

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CONTENTS PAGE

CONTENTS (Continued) Page

CONTENTS (Continued) Page

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

ABSTRACTS FROM THE JOURNAL 'CYBERNETICS'

Kiev KIBERNETIKA in English No 5, 1978 pp 153-160

[Text] ABSTRACTS

Certain Problems of Creation and Development of the Computing Engineering and Cybernetics Methods and Means Confronting the Young Scientists of the Institute of Cybernetics of the Academy of Sciences of the Ukrainian SSR.
Glushkov V. M., pp 3-5

The article deals with the most important and promising directions of the development of computing engineering and automated control systems, main problems and tasks confronting the young scientists and specialists of the institute in the field of development of new methods and technical means of cybernetics.

UDC 51:681.3.01
On Transformation of Asynchronous Logical Circuits
Nikolenko V. N., pp 6-8

Two formal transformations of asynchronous logical circuits are considered: simultaneous decomposition and superposition. Sufficient conditions are formulated for these transformations being admissible in the initial circuit. Test of these conditions holding is reduced to the test of certain simple decompositions admissibility in the same circuit.
2 fig. Refs: 5 titles.

UDC 62-5:681.3:007
Degrees of Unsolvability of Algorithmic Problems Connected with Automata Operation on Groups.
Smikun L. B., pp 9-12

The Turing degrees are considered for algorithmic problems connected with automata operation on the free Abelian groups of the rank above unit. The connection is established between the automata equivalence problem and automata stopping problem.
Refs: 4 titles.

UDC 519.683

Interactive Data Structures Processing

Bublik V. V., Doroshenko A. E., Krivoj S. L., Ljabakh V. F., pp 13-18

The paper deals with main principles of the interactive data structures processing in automatic algorithm design. Adjustable language of the data and its implementation, organization of computations and main instructions applied to the interactive processing are described. The examples are presented for the data language adjustment and application of the developed means to the programs optimization.

3 figs. Refs: 11 titles.

UDC 518.12

On One Iteration Method for Problems Solution

Gladkij A. V., Skopetskij V. V., pp 19-21

A difference analog and iteration method for solution of the boundary value problems for the elliptical equation in the rectangular region with sections are considered. A difference scheme of the second order of approximation is suggested for the numerical solution. A rapidly converging iteration process is constructed on the basis of the obtained estimates for the difference operator.

1 table. Refs: 3 titles.

UDC 519.21

On One Model of Two-Level Systems for Information Processing with Interruption

Akimov A. P., pp 22-26

A problem is considered to analyze a two-level system of information processing with losses, interruption of requirement service, two simplest input requirement flows, restricted number of information storage positions and exponential rules for distribution of processing times and service device failures.

3 figs. Refs: 3 titles.

UDC 519.9

Structural Analysis in Algebra of Analog-to-Digital Converter (ADC)

Nikitin A. N., pp 27-29

Algorithmic models are suggested for a wide class of ADC. The models are written by means of the apparatus of a system of algorithmic algebras of ADC as an efficient means of the formalized study of ADC. The time-apparatus characteristics of ADC are determined by the suggested models and methods of structural analysis.

1 table. Refs: 5 titles.

UDC 681.326.32.00
Optimum Coding of Microcommands in Representation of Microoperations by Elementary Conjunctions
Belitskij R. I., Syrov V. V., pp 30-33

A problem is solved for optimum in capacity coding of microcommands with the preset structure of the block to form controlling signals of the microprogram control device when the logical functions possess the form of elementary conjunctions with the preset rank.
1 fig. Refs: 1 title.

UDC 518.12:681.3.01
Specialized Processes Operation Algorithms for Solving Systems of Equations
Tret'jakov S. I., pp 34-36

The paper deals with problem-oriented process operation algorithms for solving systems of linear algebraic equations. Peculiarities of the algorithms consist in replacing the operation of full-digit multiplication by the shift operation. This makes it possible to obtain high-efficiency algorithms and original simple structures implementing them.
Refs: 5 titles.

UDC 007:51
Representation of Surfaces in Automatic Design Systems
Mikhajlov V. M., pp 37-40

The matrix representations of the three-dimensional graphical objects in the automatic design systems are considered.
In particular, the matrix representation of surfaces of the first, second order and of approximating spatial quadrangles is determined.
Refs: 3 titles.

UDC 62-50:519.8
Resource Control in Systems of Full-Scale Experiment Data Processing
Kornienko, G. I., Sheverda, O. N., pp 41-45

A procedure is suggested for controlling external resource of the system for full-scale experiment data processing. The procedure is based on the file system. Analysis is given for peculiarities of the information environment of the systems for full-scale experiment data processing which produce an essential influence on resource control.
2 figs. Refs: 7 titles.

UDC 517.2
On Differentiability of Set-Valued Mappings
Nurminskij E. A., pp 46-48

The convex-valued multifunctions are considered and the notion of their derivative is introduced. The differentiability criteria of set-valued mappings and the derivative relation to the extrama of different mapping functionals are studied.

Refs: 6 titles.

UDC 007:518.9
Methods of Minimizing Functions Satisfying the Lipshits Condition with Averaging the Descent Directions
Gupal A. M., pp 49-51

The paper deals with numerical methods of the centres and conjugate subgradients type for minimizing functions satisfying the Lipshits local condition. The methods are based on the functions values calculations.

Refs: 5 titles.

UDC 517.5:519.8
Algorithm for Finding the Value of Global Extremum for the Functions of Several Variables with Preset Accuracy
Babij A. N., pp 52-56

A problem is considered on finding absolute extremum for the Lipshits function of several variables. A new algorithm of finding is presented and substantiated, the recommendations on its practical application are given.

Refs: 5 titles.

UDC 517.5:519.8
Nonlocal Minimization Algorithms of Undifferentiable Functions
Norkin V. I., pp 57-60

A new class of undifferentiable (generally differentiable) functions is introduced. It includes continuously differentiable, convex and concave functions. The minimization algorithm is substantiated for such functions of the generalized gradient descent type.

Refs: 19 titles.

UDC 519.8:681.3.06
Principles for Organization of the PIONER Dialogue Optimization System
Zhelikhovskij A. A., pp 61-65

The article deals with the principles of construction and structure of the PIONER dialogue system on the basis of the BESM-6 electronic computer. The system is oriented to solving problems of nonlinear and stochastic programming with nonsmooth target and constraint functions. Main functional capabilities of the PIONER system are briefly described.
Refs: 3 titles.

UDC 62-50:519.8
On Necessary Optimality Conditions in the Stochastic Smooth-Convex Problem of Optimum Control with Discrete Time
Bordunov N. N., pp 66-68

The necessary optimality conditions are obtained in case when the phase variables belong to the space L_{1v} and the operator presetting the object dynamics is not differentiable with respect to Freshe.
Refs: 3 titles.

UDC 518.9
On Linear Differential Game of Several Persons with the Limited Control Life
Rappoport I. S., pp 69-73

Linear differential game of chaising with participation of several persons is considered in the presence of integral limitations for the control. A certain general scheme is suggested to obtain sufficient conditions of chaising completion for the finite time.
Refs: 9 titles.

UDC 007:518.5
Comparison of Some Methods to Calculate Lower Estimates for Duration of the Shortest Schedules
Laptin Ju. P., pp 74-78

Two known methods are compared: a method of the Lagrangian factors (or method of dual estimates) and the Fernandes-Bessel method.
An example is constructed. A modification of the method of dual estimates is suggested permitting the accuracy of the obtained estimates to be essentially improved.
1 fig. Refs: 9 titles.

UDC 519.21
On One Generalization of the Neumann-Pirson Lemma in the Theory of Signals Identification
Kuk Ju. V., pp 79-82

The paper deals with the structure of a critical function of statistical criterion for identifying from noise one or several determinate or random signals under which the risk of false alarm is minimized with the preset probabilities of signal missing.
Refs: 6 titles.

UDC 007:518.9
Methods for Finding Optimum Sets
Gajvoronskij A. A., pp 83-86

The optimum sets are determined for problems of mathematical programming. The parametric descriptions are suggested for these sets. The quasi-gradient algorithms of finding the descriptions for the optimum sets are developed and their convergence is studied.
Refs: 4 titles.

UDC 519.27
On a Way to Control the Calculation Accuracy in the Method of Statistical Gradient
Kaniovskij Ju. M., pp 87-89

Asymptotic normality of normalized iterations is suggested to be used for the error estimation. The estimates of a correlation matrix of the limit normal law are constructed using only the information necessary for obtaining successive approximations.
Refs: 5 titles.

UDC 519.5
Certain Properties of Antichains of Partially Ordered Sets
Kornilova L. E., Vojtishin Ju. V., pp 90-91

An effective algorithm is considered to find the maximum antichain of a partially ordered set. A lemma is presented containing conditions necessary and sufficient for the given subset of elements to be the maximum antichain.
Refs: 5 titles.

UDC 62-50:519.8
Application of the Methods of Stochastic Programming to Problems of Diffusion Processes Control
Shilo V. P., pp 92-95

The article deals with a continuous problem of optimum diffusion process control and its discrete analogue. The convergence of the discrete analogue solution to the solution of the initial continuous problem is studied. The method of stochastic quasi-gradients design is applied to the solution of the discrete problem.

Refs: 7 titles.

UDC 519.27:681.3
Optimization of Algorithms for Estimating the Random Value Under Different Operation Conditions of Data Processing
Korzhova V. N., pp 96-101

The paper deals with different algorithms for calculating mathematical expectation of a random value using the electronic computer under off-line and on-line operation conditions. The main characteristics (complete error estimate, estimates of high-speed internal memory and computation algorithms operation number) are presented for these algorithms. The characteristics may be of use when comparing the algorithms to choose the best one.

3 tables, 11 figs. Refs: 11 titles.

UDC 519.21
On the Time of Gaining the η Level Span in the Simplest Markov Random Walk
Fal' A. M., pp 102-104

As asymptotic behaviour is studied for the mean time of gaining the η level span in the simplest Markov random walk on the straight line at $\eta \to \infty$.

Refs: 3 titles.

UDC 51:621.391
On Certain Deductive Means of the System for Mathematical Text Processing
Degtjarev A. I., Zhezherun A. P., Ljalestskij A. V., pp 105-107

The article deals with the environment and deductive transformations operating in it for solving problems in various field using the apparatus of logical deduction.

Refs: 5 titles.

UDC 62-50:007:57
Simulation of Certain Oscillatory Bioprocesses
Jatsenko Ju. P., pp 108-113

A new model of a biological "predator-victim" community is suggested with regard for delay on the basis of V. M. Glushkov's macroeconomical model. It is shown that the system has a stationary state and admits variations in the species number. The model is also applied to explaining variations in the number of one species population.
Refs: 10 titles.

UDC 681.3.06:51
ANALITIK-74
Glushkov V. M., Grinchenko T. A., Dorodnitsina A. A., Drakh A. M., Kapitonova Ju. V., Klimenko V. P., Kres L. L., Letichevskij A. A., Pogrebinskij S. B., Savshak O. I., Stognij A. A., Fishman Ju. S., Tsarjuk I. P., pp 114-147

An algorithmic language ANALITIK-74 is presented for the description of calculation processes applying the transformations. The language is the further development of the language ANALITIK.
6 tables. Refs: 1 title.

BRIEF COMMUNICATIONS

UDC 007:519.8
On a Method of Undifferentiable Optimization
Glushkova O. V., pp 148-150

A minimization algorithm of convex nonsmooth functions is considered which combines certain advantages of the relaxation and unrelaxation approaches, its convergence is proved. This algorithm makes it possible to accelerate the process of finding the minimum point as compared to the method of designing generalized gradients.
1 fig. Refs: 6 titles.

UDC 512.9:681.3.06
Algorithm for Electronic Computer Construction of Automorphisms and Solution of the Problem of Finite Groups Isomorphism
Vasil'jev Ju. P., pp 151-152

An algorithm is suggested for electronic computer construction of automorphisms and finding isomorphous mapping for the preset finite groups. The constructed algorithm is programmed in the ALGOL-60 language and realized for the external automorphisms of such non-Abelian groups of the 2^6 order that their square is the internal automorphism.
Refs: 4 titles.

CSO: 1852

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

KOMSOMOL ROLE IN UKRAINIAN CYBERNETICS INSTITUTE DETAILED

Kiev KIBERNETIKA in Russian No 5, Sep-Oct 1978 pp 1-2

[Text] The Komsomol of the Nation of Soviets is sixty years old. The entire Soviet people greets this anniversary with great labor and patriotic enthusiasm. The youth of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences makes up a third of the collective's scientific potential. The more than 20 years' history of our institute bears witness that its young scientists, occupying responsible posts in science, are conducting a bold scientific quest and are doing everything possible to speed up the incorporation of the results of research into the national economy. They have made significant contributions in the development of the theory of digital automata and mathematical machines, in the theory of optimal solutions and of mathematical methods of planning and management of the national economy, in computer software, system modeling and the development of automated systems for control of industrial processes, enterprises and sectors of the national economy, and in the development and introduction into production of the KIEV, Promin', MIR-1, Kiev-67, MIR-2, Dnepr, Dnepr-2, Iskra, Ros', MIR-3 and other SESM [? series of electronic calculating machines] computers.

The Komsomol organization of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences has nutured a large galaxy of winners of Komsomol-youth prizes and contests. Doctors of Physical and Mathematical Sciences Yu. V. Kapitonova, A. A. Letichevskiy and V. V. Shkurba and Candidate of Technical Sciences V. K. Kuznetsov became Lenin Komsomol prizewinners in science and technology during their Komsomol years. The prize of the republican Komsomol organization imeni Nikolay Ostrovskiy was received by deputy director of the institute and Corresponding Member of the USSR Academy of Sciences A. A. Stogniy, Doctor of Physical and Mathematical Sciences B. N. Pshenichnyy, deputy director of the Special Design Bureau for Mathematical Machines and Systems Candidate of Technical Sciences G. I. Kornienko, Candidates of Sciences A. A. Morozov, A. A. Kobozev, V. I. V'yun, V. V. Skopetskiy, M. I. Dianov and V. I. Dianov, and leading designers M. P. Malevanyy, V. M. Mikhaylov and V. V. Gayduk. Many of the Komsomol prizewinners became winners of the USSR and Ukrainian SSR State Prizes.

In 1978 the title of "Best Young Inventor of the Ukraine" was awarded to Komsomol member L. Zubko, and the prize of the All-Union Society of Inventors and Innovators was won by V. Syrov. Winners of the All-Union Conference of

Scientific and Technical Organizations prize A. Mikhaylishin and L. Baran are working in the collective.

In 1977 the Komsomol organization of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences was awarded the Diploma of the Ukrainian Komsomol Central Committee for its great work in the communist nurturing of youth. The Komsomol took under its patronage the construction of the Cybernetics Center of the Ukrainian Academy of Sciences, an all-union shock Komsomol project. At present the construction of a scientific experimental plant for microelectronic devices, whose successful startup will make it possible to decrease the time for incorporation of our institute's developments into extensive practical use, is the subject of particular attention from youth.

The work of the Komsomol organization and the Council of Young Scientists and Specialists of the Institute of Cybernetics in patronage of the development and incorporation of computer equipment and automatic control systems is widely known. The work experience of the Cybernetics Schools of the Institute of Cybernetics, in which young engineering and technical personnel from plants and industrial associations who are working with computer equipment are trained or retrained, has been approved by the Komsomol Central Committee. The Institute of Cybernetics has organized a system for selection and training of personnel for this country's science. For more than fifteen years, leading institute scientists and youth have been working actively in the Iskatel' Small Academy of Sciences for Students in the Crimea, and in the schools in Kiev which are under their patronage. Each year the finals of the republican Olympics on "The Student and Scientific and Technical Progress" are held in the institute. As a new addition, the "Young Specialists' Days," during which meetings with labor veterans and developers of the first domestically-produced computers take place, are being organized.

The Komsomol committee and the Council of Young Scientists and Specialists have concluded and are successfully fulfilling agreements on scientific and technical cooperation with the Komsomol organizations of plants and factories designed to accelerate the incorporation of institute developments into the national economy.

The external ties of the Komsomol organization are extensive and varied.

In April 1978 the Institute of Cybernetics held a conference of young scientists and specialists in honor of the 18th Komsomol Congress and the 60th Anniversary of the Leninist Komsomol. Its main purpose was to stimulate the creative growth of young researchers, to further raise their scientific level and to acquaint with modern problems and tasks of cybernetics and draw into active work on scientific subjects those young people who are making their first steps in science.

Leading institute scientists were invited to give lectures on problems of development of research in cybernetics.

Chairman of the conference organizing committee Corresponding Member of the Ukrainian SSR Academy of Sciences Ye. L. Yushchenko delivered remarks at the opening of the conference.

The report of Academician V. M. Glushkov, "Some Tasks in the Creation and Development of Cybernetic and Computer Methods and Equipment Awaiting Young Scientists of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences," in which he spoke of the most important and promising directions of development of computer engineering and automatic control systems and of the main problems and tasks in the development of new cybernetic methods and equipment awaiting young scientists and specialists in the institute, was listened to with great attention.

The work of the conference was carried on in six sections: theoretical and economic cybernetics, technical cybernetics, system software, physical-technical and theoretical problems of computer engineering, cybernetic engineering, and biological and medical cybernetics.

More than 150 works, the best of which were recommended for publication in the journals KIBERNETIKA, UPRAVLYAYUSHCHIYE SISTEMY I MASHINY and AVTOMATIKA, were delivered at the sectional meetings.

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

GLUSHKOV LISTS TASKS OF YOUNG UKRAINIAN CYBERNETICS RESEARCHERS

Kiev KIBERNETIKA in Russian No 5, Sep-Oct 78, pp 3-5

[Speech by Academician V. M. Glushkov at conference of young scientists and specialists in honor of the 18th Komsomol Congress and the 60th anniversary of the Komsomol, held at the Institute of Cybernetics, Ukrainian SSR Academy of Sciences in April 1978: "Some Tasks in the Creation and Development of Cybernetic and Computer Methods and Equipment Awaiting Young Scientists of the Institute of Cybernetics, Ukrainian SSR Academy of Sciences"]

[Text] The current stage of development of cybernetic science is perhaps characterizable in terms of the most intense utilization of computer facilities. Essential in this connection is the fact that in a single experiment or study a large variety of equipment, generally developed concurrently, must be used. This means that present-day cybernetic researchers must have mastered the art of systems programming. This approach presupposes that the researcher or experimenter have not only experience in working with one type of computer system or a certain range of equipment for automation of programming and organization of the computation process on the computer, but also profound knowledge and understanding of the internal mechanisms of operation of modern computer systems and methods of effectively adapting them or even restructuring them for the class of tasks in question.

There have been several periods in the history of programming. Each of them had its own characteristic range of programming facilities. The development of these facilities involves on the one hand the effort to bring them closer to the concepts with which the worker is dealing, while on the other hand the requirements for effective computer solution of problems make these facilities reflect the characteristics, structural properties and internal (machine) mechanisms of computer organization. Thus, no matter what program the modern programmer is developing (whether it be for identification of processes in an ASU, sample identification, solution of a system of equations in linear algebra or graphic optimization), he must develop not only a program package embodying the algorithm for solution of the problem in question, but also a special control program (or sometimes a special operating system), a dialog system by which the user can interact with the programs of the package being developed, and other necessary services. Moreover, for this class of tasks it is almost always advantageous to have a special programming system whose use significantly increases the programmer's labor productivity.

Programmers may be classified in three categories according to their skills: systems programmers, working in the area of improvement of programming facilities in the current sense of the term, programmers who know some technology and can embody the results of their activity in some specific area as packages or special systems of programs, and finally the broad range of users with a minimum of programming knowledge who are specialists in a particular area. Let me note that programming is an essential tool for the modern cybernetics researcher carrying on computer experiments; the greater his skill, the more quickly he can arrive at the goal of his investigations.

In our institute, a series of efforts are under way involving development of new programming facilities. A method of formalizing technical requirements for program planning has been developed, the State Commission has issued a PTK (programmer's technical complex, an automated system for production of programs is under development, and so on.

In addition, efforts to develop and master data banks, in particular for the Oka, Pal'ma and similar systems, is under way.

An extremely important tasks is that of providing programmers with working conditions under which these systems will be "tied" together into a unified complex.

Our computer center is currently passing through a stage in which new working conditions and new requirements for users are being organized. This is related to the major research and experimental work being conducted by the computer center aimed at mastering the new computer equipment in the Unified Series developed in CEMA (an agreement in this connection was adopted recently).

In addition, the computer center is planning to increase sharply its complement of peripherals, particularly large-capacity disks. One of the most important tasks connected with this is that of complexing the equipment used with computers. This task must be performed not only for the specific equipment of the Unified Series and equipment of various machines with instruction systems differing from those of the Unified Series, but also in terms of complexing of programming equipment. This task is also associated with the further conversion of our computer center into a high-output collective-use remote-access computer center. The participation of young researchers in this great and important effort is extremely desirable. It should be noted that the work involves certain inconveniences and difficulties: almost continuous replacement of machines and the almost complete incompatibility of programming equipment during the transition from lower-level to higher-level Unified Series models (which in principle should not happen).

Considerable attention is currently being devoted to problems of automating scientific research. This question was discussed at the first meeting of the presidents of the academies of sciences of the CEMA countries held not long ago in Moscow. The solution of this problem depends greatly on the correct utilization of computer equipment. It includes not only and not so much the solution of problems of processing the results of experimental work; it involves rather a series of other tasks of an investigative and particularly an organizational character, such as development of the special programming systems and packages to which I have already alluded, systematization of design work, development of powerful collective-use computer centers, the development of computer networks including specialized data banks geared to a special use area, and so on. In particular, the Ukrainian SSR Academy of Sciences has begun to develop several such data banks, for example in the Institute of Materials Science. Awaiting us is the task of developing and incorporating the proper software and hardwa for this work, particularly for the Ukrainian SSR Academy of Sciences. The problems of developing a network of computer centers are interesting because the prerequisites for connection of our networks to European systems, and through them to Americal systems, are already in existence. This prospect is of interest in terms of the possibility of utilizing new computer capabilities and in terms of unification of the efforts of Socialist countries to develop specialized data banks. In addition this involves the utilization of international standards of information science and also the exchange and sale of computer hardware and software.

We now consider the tasks arising in connection with the development of various types of automated control systems. In this area the center of gravity is shifting to the solution of problems involving development of hardware-software complexes designed for specific uses. As regards ASUP [automated systems for production control], we must think in terms even of developing integrated hardware and software complex which will perform not only control tasks but also tasks of design and of automating the testing of products. The approaches to solution of this complex tasks still await investigation. Let me list the levels of integration in control systems: the first is integration of the information base; the second is integration of organizational control with control of industrial processes; and the third is addition of design and testing of products to the existing stages. The Unified Series already has the hardware to carry out the first level, even though it is insufficiently mastered and perfected. Much still remains to be done on the second and third levels. Implementation requires the ability to solve problems of developing hardware-software complexes. Here there arises a series of complex problems, among which I will mention the following: complexing of hardware and software features of computer facilities, generation of operating systems for such complexes, solving of problems in unification of equipment features, and, most important, development of the required interface equipment. Similar tasks arise in the development of systems for automated planning of various classes.

Out institute is conducting work on automated design systems. I refer to the PROYEKT system (automated computer design), the automated system for design of construction members, the system for automation of machine building design and others. The development of these systems is associated, first, with translation to new machines, and second, with expansion of their capabilities in connection with work on ARM's and other peripheral equipment. In all this work and also in the development of hardware-software complexes which will make it possible to support any design bureau, regardless of its size and profile (in the machine building, instrument making and construction areas), the problem of unification is particularly important. It requires performance of a very large amount of work, both in development of the required facilities and in specific implementation of the program of scientific experiments by the Academy of Sciences. Also important in the development of hardware-software complexes is the development of a BARS [? large-scale automated switching system]. This programmable multiplexer, let me add, is extremely important for the performance of automated document circulation tasks. The BARS is a universal device for a programmable interface system for various classes of input devices. Currently one of the tasks is that of implementing this system using microprocessors.

The following tasks can be identified in work on minicomputers: 1. mastery of SM's [system of small computers] and minicomputers which have already been produced or are about to be produced by industry as components of computer systems; 2. determination of utilization characteristics of mini and macro computers; and 3. development of new mini and macro computers which in some sense continue the line of machines in the MIR series. It is desirable in this connection that the developments should be used in work on the System of Small Computers. Contiguous with this area is the work on collective intelligent terminals, which will significantly simplify user interaction with the computer.

In our work on recursive computers, there still remains the pressing task of deparalleling of control. It is closely connected with the prospect of developing new types of microprocessors and LSI's. The problem of switching a large number of processor elements is important. Also interesting is the trend of work on automated planning of multiprocessor systems, and accordingly on development of the corresponding automation facilities.

We now consider the tasks arising in work on aritifical intelligence. At present the institute is conducting a series of studies which are still independent, although their later gradual integration into a single complex is planned. One of the most important of them is work on automation of the search for proofs of theorems and processing of mathematical texts. A labor-consuming and at the same time interesting job is the making up of information files of mathematical texts and the improvement of the system for interaction of the mathematical researcher with the program system to be developed for the Unified Series. Of considerable significance is the beginning of work on the development of machine models of the "universe." This means, of course, of limited "universes" and the means of describing them. The aim of these studies is to use their results for further progress in such areas of artificial intelligence as robots, pattern recognition, automated translation, decision making in complex situations and so on. While the model describes a limited "universe" and accordingly the semantic connections are, as it were, custom-made, nonetheless effective facilities for solving the problems in question are possible. Work on the simulation of "universes" is currently being carried on through development of program complexes. At the same time it would be advantageous to expand work on the development of special LSI's and microprocessors for robots and inhomogeneous systems. But even now we should be directing our attention to the tasks of unification, classification and forecasting of components of LSI's and microprocessors.

As regards work on mathematical methods, I will not classify them; I will say only that we have great need of all methods which we are developing: optimization methods, methods of reliability analysis, large systems simulation, numerical methods of solving equations and so on.

In our work on these methods we must attain two ends: a high worldwide level of work which will receive the proper objective evaluation, and the development of the required program packages, i.e. the computer realization of mathematical resources that have been developed. The package organization of these methods is extremely important.

I have enumerated far from all the tasks on which our young researchers could work fruitfully. We expect that with the enthusiasm, persistence and boundless energy characteristics of youth they will continue the search for new ways of developing cybernetic science and its associated areas in the national economy to the advantage of our Fatherland.

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GEOPHYSICS, ASTRONOMY AND SPACE

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EXPERIMENTAL INVESTIGATIONS OF THE MAGNETOSPHERIC PROPAGATION OF SHORTWAVE SIGNALS ALONG AN EARTH-EARTH PATH

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[Article by G.V. Bukin, USSR Academy of Sciences Institute of Terrestrial Magnetism, the Ionosphere and Radiowave Propagation]

[Text] With reference to data obtained in the territory of the Soviet Union and on craft of the USSR Academy of Sciences Space Research Service sent out into magnetically linked areas, experimental data are discussed, regarding the magnetospheric propagation of shortwave signals during the period of high and low solar activity.

As the result of synchronous experiments conducted in the territory of the Soviet Union and on scientific research vessels (NIS's) sent out into magnetically linked areas (MSO's), abundant experimental data have been obtained on the magnetospheric propagation of shortwave signals. Magnetospheric channels trace out on the surface of Earth zones of effective reception with cross dimensions of from 100 km and less [1]. Therefore, from the viewpoint of identifying these zones, observations on moving barges are advantageously distinguished from observations at a fixed point.

The purpose of this paper is to attempt to prove the existence of a magnetospheric signal along an Earth-Earth path, for which it is necessary to summarize all the results of our experimental investigations of a magnetospheric shortwave signal, beginning in 1968, when the NIS "Borovichi" was sent out for the first time into the MSO toward Gor'kiy. Then these investigations were continued and were conducted under different forms of solar and magnetic activity, at different times of the year and at different times of the day and night. The equipment and methods of processing primary data from trip to trip have been improved more and more. Shortwave and VLF signals have been emitted from the territory of the Soviet Union and received on vessels, and pulsed shortwave signals have been emitted from ships and received in the territory of the Soviet Union, where in this instance measurements were made of the angle of arrival of signals by means of a direction finder [2] and by means of the UTR-2 radio telescope of the Ukrainian SSR Academy of Sciences

Khar'kov IRE [Institute of Radiophysics and Electronics]. Installed on vessels were vertical ionospheric probe equipment, riometric units, etc.

The analysis of outer-space-probe ionog ams from the "Alouette-1," "Alouette-2" and "Kosmos-381" satellites has confirmed the existence of inhomogeneities heavily extended along the geomagnetic field and has given direct proof of the propagation of shortwave radiowaves along these inhomogeneities along magnetosphere-magnetosphere [3] and magnetosphere-Earth [4] paths.

In studying the propagation of signals along an Earth-Earth path, the major difficulty is separating out the magnetospheric signal against a background of other anomalous signals. As demonstrated by an experiment conducted in October 1968, when the shortwave transmitter installed in Gor'kiy was operating in the pulsed mode, emitting pulses with a length of 1 ms with a transmitting cadence of 4 Hz, and reception took place on the NIS "Borovichi," sent out into the MSO toward Gor'kiy, a great diversity of anomalous signals has been recorded [5]. Among these have been signals which match magnetospheric propagation with respect to propagation time. But there have also been signals of distinctly non-magnetospheric propagation with the same time delays, which has made a definite interpretation of the results impossible. Therefore, in 1970 the experiment was repeated, but this time two NIS's were sent out into the MSO--the "Borovichi" and "Nevel'" [6-9], whereby the NIS "Borovichi" was in the MSO during November, and the NIS "Nevel'" at the same time constructed profiles along the north-south and east-west lines of this area. Equipment of the same type was used on these vessels. The operating frequency range of the Gor'kiy transmitter was expanded from 8 to 13 MHz (1968) to 5 to 15 MHz (1970). Investigations of the magnetospheric signal were made both in the period of high and low solar activity.

Period of High Solar Activity

On the NIS "Borovichi" in 1968 and 1970 nearly simultaneous measurements were made in the SW and VLF (15 kHz) bands, of signals emitted from Gor'kiy. In fig 1 is shown the relationship between the propagation time of magnetospheric VLF (t_{ONCh}) and SW (t_{KV}) radiowave signals ($t_{KV} = \tau_{KV} + t_0$, where τ_{KV} is the delay time of the magnetospheric signal in relation to the fundamental signal, and $t_0 = 39$ ms is the mean delay time of the fundamental signal), plotted from data for these years. This relationship has already been given for 1970 in [10]. In fig 1 this relationship has been supplemented with data for 1968 (three values), whereby t_{ONCh} and t_{KV} were determined with reference to the leading edge of the signals. It is obvious that all values form three clusters of points: Cluster I corresponds to signals re-emitted from the American sector, cluster II from the Australian sector, and the third group of points lies fairly well on a straight line for $t_{KV}(t_{ONCh})$, and it can be assumed with high certainty that these are SW signals of magnetospheric origin. In table 1 is given the delay time of magnetospheric SW and VLF signals, the date and time they were observed, and frequencies of the SW signal. It is obvious that a magnetospheric SW signal has been observed only in the morning (0330 hours to 0500 hours MSK [expansion unknown]) and evening (1630 to 2030 hours MSK) hours. A re-emitted signal has also been observed in the morning and evening hours, but over a considerably greater time interval. In fig 2 are given f(t) curves obtained from the data of vertical ionospheric probes on the "Borovichi" (1), at Gor'kiy (2), at Rostov (3) and at Alma-Ata (4). The boundaries of the occurrence of a magnetospheric signal are plotted by the dashed lines, and the ranges of occurrence of side propagation of signals are hatched. As is obvious from fig 2, a magnetospheric signal is observed when the critical frequencies in the area of the transmitter and in the MSO become close to the operating frequency of the transmitter, taking into account the oblique incidence of the signal onto the ionosphere. Apparently the most favorable moments of time for the creation of plasma waveguides stretching along Earth's geomagnetic field are periods of predawn and presunset phenomena in the ionosphere, when the transfer of photoelectrons takes place from one hemisphere to the other [11]. At these moments collisionless heat waves are propagated between conjugate points [12]. This can result in the reduction of the electron concentration over a fairly narrow range determined by the ionosphere's irradiance, which is necessary for the creation of plasma wave channels [13]. These channels are entered most effectively at their end, and therefore propagation takes place in a few smaller L-shells.

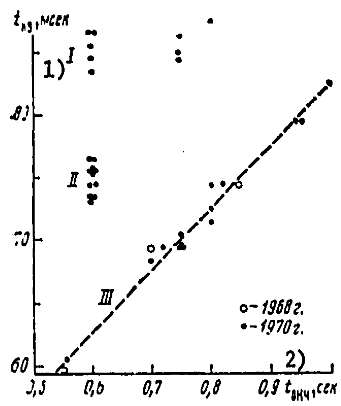

Figure 1. 2.

Key:
1. t_{KV}, ms
2. t_{ONCh}, s

It is also obvious from table 1 that a magnetospheric signal is observed during the period of maximum solar activity at frequencies of from 8.8 to 12.3 MHz, and a re-emitted signal practically over the entire frequency band which we selected, i.e., from 5 to 15 MHz.

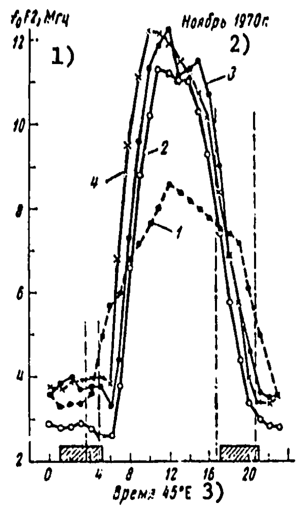

Figure 2.

Key:
1. f_0 F2, MHz
2. November 1970
3. Time, 45°E

Also of interest is the relationship between t_{ONCh} and t_{KV} and the K_p index for a magnetospheric signal (fig 3). At first t_{ONCh} and t_{KV} are reduced with an increase in K_p to 2.5 to 3.5, and then they begin to increase (the last point has been plotted only for one value of t_{ONCh} and t_{KV}). This fact finds an explanation in the shortening and stretching out of lines of force in different phases of disturbance. The contraction and stretching of lines of force can reach for the latitudes considered about 10 to 20 percent [14], and, consequently, can explain variations in the magnetospheric signal. As far as the linear relationship between t_{KV} and t_{ONCh} is concerned, it can exist only with a synchronous change in the paths of SW and VLF radiowaves.

Magnetospheric signals along an Earth-Earth path are usually observed with double magnetoionic splitting, with $\Delta\tau \sim$ 2 to 3 ms, but because of the low resolution of the equipment used they are usually seen as a single heavily broadened signal.

Table 1.

Дата приема 1)		Время приема 2)		$f_{кв}$, Мгц 8)	$t_{кв}$, мсек 9)	$t_{онч}$, сек 10)
КВ-сигнала 3)	ОНЧ-сигнала 4)	КВ-сигнала	ОНЧ-сигнала			
5) октябрь 1968 г.		7)				
17	17	03 ч. 30 м.	07 ч. 00 м.	10,3	59	0,55
24	24	04 00	07 00	11,8	68	0,70
25	25	19 30	21 00	12,0	74	0,84
6) ноябрь 1970 г.						
7	6	04 30	20 00	8,9	74	0,80
7	7	16 35	20 00	12,0	71	0,80
10	9	04 50	23 00	12,0	61	0,65
11	11	03 35	07 00	8,9	79	0,95
16	16	03 35	07 00	8,9	79	0,95
17	17	03 30	07 00	8,9	69	0,75
17	17	03 35	07 00	8,9	69	0,75
18	17	03 35	23 00	8,9	72	0,80
19	19	03 35	07 00	8,9	82	1,0
19	19	17 35	23 00	12,3	68	0,70
21	21	19 30	20 00	10,0	69	0,75
21	21	19 35	20 00	10,1	69	0,75
21	21	20 35	20 00	8,8	70	0,75
29	20	04 30	07 00	8,9	74	0,82

Key:

1. Date of reception
2. Time of reception
3. SW signal
4. VLF signal
5. October 1968
6. November 1970
7. 0330 hours
8. f_{KV}, MHz
9. t_{KV}, ms
10. t_{ONCh}, s

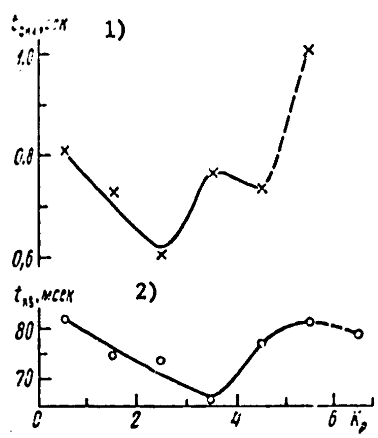

Figure 3. [Key on following page]

Key:
1. t_{ONCh}, s
2. t_{KV}, ms

Period of Low Solar Activity

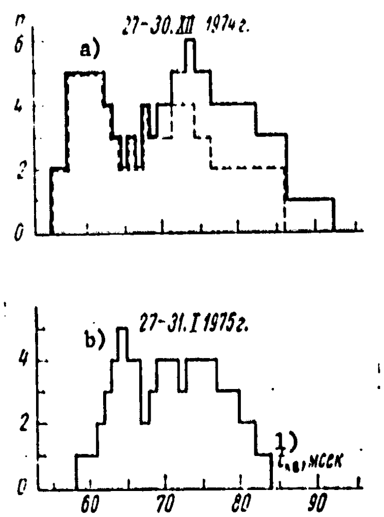

Figure 4.

Key:
1. t_{KV}, ms

During the period of the solar activity minimum, the concentration in the equatorial plane in the magnetosphere is reduced approximately threefold as compared with the years of maximum solar activity, as can be concluded from the data of VLF measurements. This results in the fact that magnetospheric signals arrive very weak, and in order to register them it is necessary to resort to the pulse storage method. In this instance on one of the vessels was installed a noncoherent digital pulse storage unit, which made it possible to store from 80 to 9000 pulses.

During the time of the 1974-1975 expedition data were obtained which made it possible to isolate anomalous modes at f = 5.65 MHz. The most important results of this experiment are given below.

In fig 4a is shown the number of cases of reception after storing the pulses of anomalous signals, in relationship to the magnitude of the relative delay during the time the NIS was in the MSO from 27 through 30 December 1974.

The solid-line histogram includes all anomalous morning and evening signals, and the dashed-line excludes anomalous evening signals observed only in the MSO.

For the purpose of comparison, in fig 4b a histogram has been constructed for when the NIS was near Kerguelen Island from 27 through 31 January 1975. It is obvious from figs 4a (dashed-line histogram) and 4b that in the distribution of n(t) there are two characteristic maxima, which resolve all anomalous signals into two groups: I--t < 66 ms, and II--t = 66 to 86 ms. It should be noted that the histograms are similar for both observation periods. Taking into account signals characteristic only of the MSO, the nature of the distribution of n(t) in fig 4a (solid line) differs but slightly from the histogram given in fig 4b. First, the range of t_{KV} increases to 93 ms, and, then, the second maximum surpasses the first.

Having available only time delays and estimates of the amplitude and shape of the signal, it is difficult to make a definite interpretation of the types of signals registered on the NIS in 1974-1975 in the MSO and neighboring regions. Nevertheless it is possible to construct a hypothesis regarding the mechanism for the propagation of these signals.

All signals of group I were received in all sessions in various areas of the Indian Ocean. The analysis of time delays has made it possible to suggest the possibility that anomalous signals of group I arrived by side paths, with re-emission from the African Continent or with reflection from polar aurora zones. The greater part of signals of group II can be interpreted, as in experiments in 1968 and 1970-1971, by propagation along side paths with re-emission from the South American sector.

Deserving of special isolation are signals of group II which were received only in the MSO with t ∿ 72 to 86 ms in the evening (2000 to 2100 hours). Signals with these delays were not received outside the MSO in 1974-1975 during the interval of 2000 to 2100 hours. The group II signals isolated here can correspond to magnetospheric propagation, with L ∿ 1.9 to 2.3. The critical frequencies, f_0F2, in the area of the transmitter and MSO during the reception of these signals took on values of approximately 2 to 2.5 MHz, i.e., the ionosphere was transmissive for magnetospheric signals at a frequency of 5.65 MHz.

A special role has been played by observations which included measuring the solid angles of arrival of the magnetospheric signal. Because of the unwieldiness of direction finder antenna systems, it is not possible to set them up on vessels. Therefore, powerful transmitters were in operation on vessels, and solid angles were measured from the territory of the Soviet Union. A disadvantage of this method is the comparatively high noise level from nearby industrial sites.

During the period from 8 through 12 April 1976, the NIS "Kegostrov" was sent out into the area of the MSO toward Khar'kov (ϕ = 36°S, λ = 50°30'E) and emission was carried out by means of a powerful transmitter of the "Vyaz" type, and reception took place in Khar'kov with the UTR-2 radio telescope of the Ukrainian SSR Academy of Sciences Khar'kov IRE. The study continued to 15 April and the objective was to study the solid dimensions of the area for reception of the magnetospheric signal as the "Kegostrov" left the MSO. The length of the transmitter's pulse equaled about 1 ms, and the transmitting frequency was about 5 Hz. The "Vyaz" radio transmitter was loaded with a non-directional antenna.

Operation took place at 10-min intervals with 10-min pauses. Observations were made from 0330 to 0520 hours and from 1800 to 2030 hours. The operating frequencies selected ranged from 9 to 14 MHz.

The 10-minute pauses between operating sessions were employed for the purpose of retuning the transmitter on the "Kegostrov" and the receivers in the UTR-2 radio telescope from one frequency to another, and for calibrating the receivers, which was done after each operating session.

In the UTR-2 radio telescope scanning was performed from 60 to 70° to 20° in the direction from the zenith to the south and back, by means of a broad directional pattern in the west-east direction and a narrow one in the north-south direction.

Observations with the UTR-2 radio telescope in April 1976 were of a research nature, and the main objective of this experiment was to determine whether it is possible with this radio telescope to measure the angle of arrival of a fundamental and anomalous, in particular, a magnetospheric, signal.

It is obvious from the photorecordings obtained with the radio telescope that in all sessions the fundamental signal was observed steadily, since the operating frequencies which we selected were lower than MPCh-4000F2. The strength of the direct signal on the photorecordings practically did not vary and depended only on the radio noise level. It was another story with the secondary signals. They arrived weaker in Khar'kov and were apparently received only by the main lobe of the radio telescope. Therefore, they were observed with a strictly fixed antenna scanning angle.

Of all the sessions (about 40) only two deserve the highest attention--when secondary signals occurred: on 11 April 1976 from 0410 to 0418 hours ($f = 12,098$ kHz) and on 13 April 1976 from 1920 to 1928 hours ($f = 10,200$ kHz). In the first instance the vessel was in the MSO toward Khar'kov, and in the second began to leave the calculated MSO in a northerly direction.

In the second instance a secondary signal was observed twice, when the scanning angle (angle read from the horizontal line) was about 46° ($\tau \sim 34$ ms) and about 54° ($\tau \sim 36$ ms). In the second instance it was also observed twice, when the scanning angle was about 50° ($\tau \sim 32$ ms) and about 60° ($\tau \sim 43$ ms). Table 2 contains the angles of arrival of the secondary signal in the vertical plane, for sessions held on 11 and 13 April 1976.

Table 2.

1) Дата	2) Время (МСК)	3) Угол сканирования, град	4) Дополнительный сигнал, мсек	1) Дата	2) Время (МСК)	3) Угол сканирования, град	4) Дополнительный сигнал, мсек
11.IV 1976	5) 04 ч. 10 м.	20	6) Нет	13.IV 1976	19 ч. 20 м.	20	Нет
	04 11	26	»		19 21	25	»
	04 12	30	»		19 22	30	»
	04 13	34	»		19 23	35	»
	04 14	38	»		19 24	40	»
	04 15	42	»		19 25	45	»
	04 16	46	34		19 26	50	32
	04 17	50	Нет		19 27	55	Нет
	04 18	54	36		19 28	60	43

Key:

1. Date
2. Time (MSK)
3. Scanning angle, degrees
4. Secondary signal, ms
5. 0410 hours
6. None

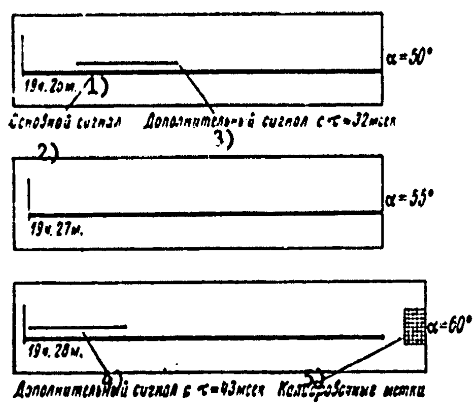

Figure 5.

Key:

1. 1926 hours
2. Fundamental signal
3. Secondary signal with $\tau \approx 32$ ms
4. Secondary signal with $\tau \approx 43$ ms
5. Marker pips

In fig 5 is given an example of a diagrammatic recording on 13 April 1976 from 1926 hours to 1929 hours. At the end of this recording marker pips are given, made for this session, which were entered every 10 ms. It is obvious that the fundamental signal was observed all the time; the secondary signals with $\tau \approx 32$ and 43 ms were observed at the beginning of minute sessions at 1926 hours and 1928 hours, which corresponds to angles (cf. table 2) of about 50 and 60°.

Although for Gor'kiy $L \approx 2.54$ and for Khar'kov $L \approx 2.02$, which is a quite substantial difference because of the great divergence of lines of force, for re-emitted signals it will be insignificant. Therefore, it is possible to take advantage of fig 1 and to estimate the nature of signal propagation. As is obvious from fig 1, signals arriving in Khar'kov can be received on account of re-emission from the American sector (signal with $\tau \approx 43$ ms) and the Australian sector (signal with $\tau \approx 32$ ms), and can also be propagated by means of the magnetosphere.

Speaking in favor of magnetospheric propagation are the wide angles of arrival of these signals in the vertical plane (about 50 and 60°). As demonstrated in [2], along extra-long radio paths direct signals and signals re-emitted from the American and Australian sectors arrive at angles in the vertical plane with a maximum at 10 to 12°.

Magnetospheric signals were observed with heightened magnetic activity ($K_p \approx 4$), while in all adjacent sessions $K_p \approx 2$, i.e., lying on the ascending curve obtained in the Gor'kiy experiment (fig 3). We tried to explain this pattern for Gor'kiy by the contraction and stretching of lines of force in different phases of disturbance. But for Gor'kiy magnetospheric signals were observed on different days with different magnetic activity. In Khar'kov two magnetospheric signals were observed practically simultaneously. This has compelled us to suggest that they were propagated through different magnetospheric channels, or that the signal was split into two magnetoionic components in the ionosphere and that then each component went its own way.

In the case which we have discussed, elementary estimates give, for $\tau \approx 32$ ms ($t_0 \approx 33$ ms), a path traveled by the signal equaling $S \approx 2 \cdot 10^4$ km, and for $\tau \approx 43$ ms, $S \approx 2.3 \cdot 10^4$ km, and the estimated distance for Khar'kov is $S \approx 2.16 \cdot 10^4$ km, i.e., the impression is created that one signal has settled on a somewhat smaller L-shell and the other on a somewhat larger. But these estimates were made without taking into account refraction and lag in the ionosphere.

Let us note that in an experiment from October 1973 through April 1974 at IZMIRAN [Institute of Terrestrial Magnetism, Ionosphere and Radiowave Propagation] measurements were made of the angles of arrival of signals in the horizontal and vertical planes, by means of a radio direction finder. In this experiment a magnetospheric signal was not recorded even once. There can be three reasons for this: 1) The study with the direction finder was conducted during a period of minimum solar activity, when observations of a magnetospheric signal were difficult; 2) the magnetospheric signal could not be observed because of a high level of industrial and radio noise; 3) it is not known whether a direction finder generally can measure such wide angles (50 to 70°) in the vertical plane with a low signal level.

The entire combination of facts cited above testifies to the existence of magnetospheric propagation of SW signals along an Earth-Earth path.

Concisely formulated below are the main results obtained from observations of a magnetospheric signal.

1. A magnetospheric signal has been observed in the morning and evening hours of a 24-hour period. This is apparently related to the periods of occurrence of the transfer of photoelectrons from one hemisphere to the other.

2. There is a definite relationship between the delay time (t_{KV}) of a magnetospheric signal and the K_p index. It diminishes to $K_p \approx 3$, and then begins to increase. These variations in t_{KV} have found an explanation in the contraction and stretching of lines of force in different phases of geomagnetic disturbances.

3. In the period of maximum solar activity magnetospheric signals are observed more frequently and at higher effective frequencies than in the period of minimum activity, which is apparently associated with the reduction in electron concentration in the plasmosphere during the period of low solar activity.

4. A magnetospheric signal is usually observed with double magnetoionic splitting. In measurements with a radio telescope, in two instances two signals were observed simultaneously: One arrived at an angle of 46 to 50° and the other of 54 to 60°. To explain this fact it must be assumed that the signal is split into two magnetoionic components in the ionosphere and then each component is propagated along its own path on account of ricocheting along walls with a heightened electron concentration.

The author wishes to express his profound gratitude to the leaders and crews of vessels of the USSR Academy of Sciences Space Research Service, to the leadership of the Ukrainian SSR Academy of Sciences IRE for the opportunity to make observations with the UTR-2 radio telescope, to associates at the laboratory of ionosphere physics and modeling for assistance in this paper, to Ye.A. Benediktov, N.A. Mityakov, O.A. Molchanov and V.O. Rapoport for their useful discussions, and also to V.F. Bryantsev for offering the data obtained by him during the 1974-1975 cruise.

Bibliography

1. Perekhvatov, Yu.K. In "Rasprostraneniye dekametrovykh voln" [VLF Wave Propagation], No 1, Moscow, Nauka, 1975, p 46.

2. Belikovich, V.V., Ben'kova, N.P., Bryantsev, V.F., Bukin, G.V., Matyugin, S.N., Protashchik, A.A. and Cherepovitskiy, V.A. GEOMAGNETIZM I AERONOMIYA, 1976, 16, 841.

3. Loftus, B.T., Vanzandt, T.E. and Calvert, W. ANN. GEOPHYS., 1966, 22, 530.

4. Benediktov, Ye.A., Bukin, G.V., Kushnerevskiy, Yu.V., Matyugin, S.N., Mozerov, N.P., Perekhvatov, Yu.K. and Fligel', M.D. KOSMICHESKIYE ISSLEDOVANIYA, 1972, 10, 302.

5. Benediktov, Ye.A., Ben'kova, N.P., Bukin, G.V., Getmantsev, G.G., Yefimova, T.V., Komrakov, G.P., Malyshev, S.K., Mityakov, N.A., Perekhvatov, Yu.K., Skrebkova, L.A. and Shilkov, N.P. GEOMAGNETIZM I AERONOMIYA, 1971, 11, 252.

6. Benediktov, Ye.A., Ben'kova, N.P., Berezin, Yu.M., Bukin, G.V., Yezhov, A.N., Kolokolov, L.Ye., Korobkov, Yu.S., Malyshev, S.K., Matyugin, S.N., Mityakov, N.A., Perekhvatov, Yu.K. and Sazonov, Yu.A. In "Voprosy rasprostraneniya korotkikh radiovoln" [Questions Relating to Short Radiowave Propagation], Part I, IZMIRAN, Moscow, 1973, 3.

7. Benediktov, Ye.A., Ben'kova, N.P., Bukin, G.V. and Matyugin, S.N. In "Voprosy rasprostraneniya korotkikh radiovoln," Part I, IZMIRAN, Moscow, 1973, 27.

8. Benediktov, Ye.A., Ben'kova, N.A., Berezin, Yu.M., Bukin, G.V., Matyugin, S.N., Mityakov, N.A. and Perekhvatov, Yu.K. In "Voprosy rasprostraneniya korotkikh radiovoln," Part II, IZMIRAN, Moscow, 1974, 3.

9. Benediktov, Ye.A., Ben'kova, N.P., Bukin, G.V., Matyugin, S.N., Mityakov, N.A. and Perekhvatov, Yu.K. In "Voprosy rasprostraneniya korotkikh radiovoln," Part II, IZMIRAN, Moscow, 1974, 17.

10. Bukin, G.V. and Molchanov, O.A. GEOMAGNETIZM I AERONOMIYA, 1976, 16, 287.

11. Bukin, G.V., Yevzovich, N.P., Katsenel'son, I.B., Sukhorukova, E.V., Yelizarev, Yu.N. and Shakhtin, Kh.Z. GEOMAGNETIZM I AERONOMIYA, 1968, 8, 940.

12. Bukin, G.V., Kozorovitskiy, L.L., Kolokolov, L.Ye. and Sobolenko, D.N. KOSMICHESKIYE ISSLEDOVANIYA, 1971, 9, 789.

13. Bukin, G.V. and Perekhvatov, Yu.K. GEOMAGNETIZM I AERONOMIYA, 1972, 12, 421.

14. Akasofu, S.I. and Chepmen, S. "Solnechno-zemnaya fizika" [Solar-Terrestrial Physics], Part 2, Moscow, Mir, 1975.

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GEOPHYSICS, ASTRONOMY AND SPACE

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IONOSPHERIC GENERATION OF EXTREMELY LOW FREQUENCY RADIATION

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[Text] An analysis is made of the results of investigations of the spatial distribution of ELF radiation at ionospheric altitudes. On the basis of this a hypothesis is advanced regarding the generation of a considerable part of the ELF radiation observed at altitudes of 300 to 400 km and an attempt is made to substantiate this hypothesis theoretically.

Introduction

In this paper, based on an analysis of experimental data on the spatial distribution of low-frequency electromagnetic radiation in the ELF range, obtained with the "Interkosmos-5" ISZ [artificial Earth satellite], the hypothesis is advanced that a considerable portion of mid-latitude ELF radiation is generated at altitudes of 300 to 400 km. Measurements were made with the "Interkosmos-5" from December 1971 through April 1972 at altitudes of 200 to 1200 km [1].

It has been established that the energy density of the radiation, W, is higher during the daytime than at night; at a fixed L-shell and altitude, during the daytime W at a frequency of $f = 0.5$ kHz depends on the strength of the local magnetic field, B_0; the intensity is markedly higher in areas with lower values of B_0; the value of W is maximal at altitudes of $h \approx 300$ to 400 km, and with an increase in h to about 1000 km the radiation level drops by approximately an order of magnitude. These patterns have not been observed at $f \gtrsim 2,5$ kHz [2].

According to current notions, low-frequency radiation (about 10 Hz to 100 kHz) is generated at mid-latitudes in equatorial regions of the magnetosphere. But it is hard to explain on this basis the experimental facts cited above. Actually, at $h > 1500$ km energetic particles and the cold plasma are balanced with respect to day and night. Consequently, the conditions for the generation of low-frequency noise radiation are identical day and night. Then, it would seem that the radiation level should be the same day and night. It is not possible to understand the effect of the 24-hour intensity cycle observed by a difference in the reflecting characteristics of the ionosphere in the daytime and at night, and, besides, absorption is less in the ionosphere at night.

The altitude dependence can be caused in principle by features of wave propagation at altitudes of from 800 to 1000 to 300 to 400 km. Since along this path the concentration of cold plasma, N_e (cf. table 1), increases by about 1.5 orders of magnitude, the refractive index, n , increases, and the velocity of a wave is reduced, on the assumption of retention of the flux density, the amplitude of the wave should be increased:

$$b \infty n^{1/2} \infty (N_e/B_0^2)^{1/4}.$$

Estimates have shown that here $W(\infty b^2)$ should be increased approximately fourfold. This effect is the same both for $f \sim 0.5$ kHz and for $f = 2.5$ kHz. But at a frequency of $f = 2.5$ kHz the altitude dependence has not been observed, and at $f = 0.5$ kHz the level of W on this path changes 10-fold. Finally, at high altitudes Earth's magnetic anomalies are not manifested and the relationship between the radiation level and B_0 does not fit the hypothesis on the generation of radiation near the equatorial region.

Table 1.

h, км		200	300	400	500	600	700	800	900
$N_m \cdot 10^{-3}$, см$^{-3}$	1) день	8900	930	200	56	17	6	2,4	1,1
	2) ночь	8400	590	78	17	3,2	1	0,48	0,29
$N \cdot 10^{-3}$, см$^{-3}$	день	5	46	15	9	4	2	1	0,7
	ночь	0,03	1	3	2	1,3	0,8	0,5	0,3
$N_{O^+} \cdot 10^{-3}$, см$^{-3}$	день	4,5	15,8	14,5	8,1	3,4	1,5	0,6	0,29
	ночь	0,027	0,99	2,9	1,8	1,1	0,6	0,3	0,12
$N_{He^+} \cdot 10^{-3}$, см$^{-3}$	день	–	–	7,5	14	8	8	6	6,3
	ночь	–	–	1,5	3	2,6	3,6	3	2,7
$N_{N^+} \cdot 10^{-3}$, см$^{-3}$	день	2,5	16	30	54	32	20	12	7
	ночь	0,015	1	6	12	10	8	6	3
$N_p \cdot 10^{-3}$, см$^{-3}$	день	–	–	15	27	24	22	21	28
	ночь	–	–	3	6	8	9	10	12
ν_e, сек$^{-1}$ 3)	день	1500	3000	1400	750	400	220	140	80
	ночь	300	200	500	300	160	100	60	40

Key:

1. Day
2. Night
3. v_e, s^{-1}

It is possible to explain satisfactorily the patterns gotten above if it is assumed that the ELF radiation observed is generated by energetic particles of radiation zones at altitudes of the maximum of the F2 layer (300 to 400 km). We know that wave generation is related to anisotropy of the function for distribution of particles by pitch angles. The distribution function is most anisotropic at low altitudes. At altitudes of $h \sim 300$ to 400 km, where the highest level of ELF radiation is observed, the concentration of cold plasma, N_e, is 1.5 to two orders of magnitude higher in the daytime than at night. Although the degree of anisotropy of the function for distribution of energetic particles by pitch angles does not vary from day to night, the conditions for generation will be different: In the daytime the refractive index is higher ($n \propto N_e^{1/2}$), and, consequently, the phase velocities of waves will be lower, and for a great number of particles the kinematic conditions will be fulfilled for Cherenkov and cyclotron radiation. In addition, the radiation intensity of each particle is proportional to n [3]; consequently, the radiation level must be higher in the daytime than at night.

If radiation is generated by energetic particles at low altitudes, then the influence of the magnetic field on the radiation level should be apparent; in areas with a reduced magnetic field (magnetic anomalies) a greater number of particles descend to low altitudes.

Initial Equations

At altitudes of 200 to 1000 km, in the ionospheric plasma, in addition to electrons there is a high concentration of hydrogen and oxygen ions. Here the number of collisions is high, and therefore it is not clear apriori whether the generation of low-frequency radiation is possible. For this purpose, quantitative estimates were made of the influence of collisions on the propagation and generation of low-frequency noise radiation at these altitudes.

The starting equations for the study were equations of electrodynamics with a self-consistent field:

$$\operatorname{rot}\mathbf{B}=\frac{4\pi}{c}\sum_{\alpha=1}^{3}e_\alpha\int \mathbf{v}_\alpha F_\alpha(\mathbf{v}_\alpha)\,d\mathbf{v}_\alpha+\frac{1}{c}\frac{\partial\mathbf{E}}{\partial t},\quad \operatorname{div}\mathbf{B}=0,$$

$$\operatorname{rot}\mathbf{E}=-\frac{1}{c}\frac{\partial\mathbf{B}}{\partial t},\quad \operatorname{div}\mathbf{E}=4\pi\sum_{\alpha=1}^{3}e_\alpha\int F_\alpha(\mathbf{v}_\alpha)\,d\mathbf{v}_\alpha \qquad (1)$$

and kinetic equations for particles of the type $\alpha = 1,2,3$ (protons and electrons of ionospheric plasma and energetic particles of radiation zones):

$$\frac{\partial F_\alpha}{\partial t} + v_\alpha \frac{\partial F_\alpha}{\partial r_\alpha} + \frac{e_\alpha}{m_\alpha}\left\{E + \frac{1}{c}[v_\alpha B]\right\}\frac{\partial F_\alpha}{\partial v_\alpha} = \left(\frac{\partial F_\alpha}{\partial t}\right)_{\text{соуд.}} \tag{2}$$

[Subscript "soud" = "collision."] In (1) and (2), $F_\alpha(r,v,t)$, e_α, m_α, and v_α are the distribution function, charge, mass and velocity of particles of the α type, and E and B are self-consistent electric and magnetic fields.

In a linear approximation, making, as in [4], simple but cumbersome computations, we get a dispersion equation for waves, $\infty \exp i\,(\omega t - kr)$, propagated along external field B_0:

$$(n - i\varkappa)^2_{1,2} = 1 - i\,\frac{\omega_{0e}^2(\omega_p^\pm - (m_e/m_p)\nu_{ep}) + \omega_{0p}^2(\omega_e^\pm - (m_e/m_p)\nu_{pe})}{\omega(\omega_e^\pm\omega_p^\pm - \nu_e\nu_p)} + \Delta, \tag{3}$$

where

$$\Delta = \frac{\pi\omega_{0s}^2}{\omega N_s}\int_{-\infty}^{\infty} dv_z \int_0^{\infty} dv_\rho v_\rho^2 \left\{\left(1 - \frac{kv_z}{\omega}\right)\frac{\partial F_s}{\partial v} + \frac{kv_\rho}{\omega}\frac{\partial F_s}{\partial v_z}\right\}(kv_z - \omega \pm \omega_{Bs})^{-1}, \tag{4}$$

$n = ck/\omega$ and κ are the refractive and absorption indices,

$$\omega_p^\pm = i\omega + \nu_p \mp \omega_{Bp}, \quad \omega_e^\pm = i\omega + \nu_e \pm i\omega_{Be},$$

ω_{Bp} and ω_{Be} are the gyrofrequencies of a proton and electron; ν_p and ν_e are the effective numbers of collisions of protons and electrons with all particles, including ions (i), and ω_{0p} and ω_{0e} are the Langmuir frequencies. Carried out in Δ (4) is the contribution of energetic particles of radiation zones to the dispersion equation (subscript s), where N_s is their concentration. The upper symbol in (3) refers to a left-polarized wave, L, and the lower to a right-polarized, R.

As we know, in an electron-proton plasma, in the frequency range of $\omega < \omega_{Be}$ ($\omega_{0e} > \omega_{Be}$), can be propagated only a right-polarized wave ($n^2 > 0$), the so-called whistler mode [5]. At the ionospheric altitudes which we have studied the concentration of cold plasma protons, N_p, is much lower than N_e; therefore, as follows from (3), a left-polarized wave can exist only in a narrow frequency range of $\omega_{Bp}(1-N_p/Ne) \lesssim \omega \lesssim \omega_{Bp}$, and we will not consider it further.

For a right-polarized wave, equating the different terms in (3), and utilizing the averaged model of the ionosphere in [6] (table 1), we find:

$$\tilde{n}_R^2 = (n - i\varkappa)^2 \approx \frac{\omega_{0e}^2}{\omega\omega_{Be}} - i\left[\frac{\omega_{0e}^2\nu_e}{\omega\omega_{Be}} + \frac{\omega_{0p}^2\nu_p}{\omega(\omega+\omega_{Bp})^2}\right] + \Delta. \tag{5}$$

Investigation of Propagation Effects

We assume below that it is possible to disregard the influence of term Δ in (5) on propagation. This is permissible in the case when the concentration of energetic particles is low, i.e. [5]:

$$|\Delta| \ll |\tilde{n}_R^2|.$$

Related to Δ is only the excitation of waves, and the addition to frequency ω caused by this term is assumed to be slight. The experimentally observed altitude dependence we relate to the features of propagation and absorption of ELF waves in the ionosphere between the levels of 300 to 1000 km.

Let us turn to a discussion of this question, omitting term Δ in (5). For the purpose of estimating the attenuation resulting from absorption, we write equation (5) in the form:

$$\Phi(\omega) - iA(\omega) = 0. \tag{6}$$

It is obvious from table 1 and (5) that at the altitudes considered in the ionosphere

$$|\Phi(\omega)| \gg |A(\omega)|,$$

therefore, for the purpose of finding the wave damping constant ($\mathrm{Im}\,\omega$), we use the method of disturbances. Introducing the symbols $\omega = \omega^{(0)} + \varepsilon$, where $|\varepsilon| \ll \omega^{(0)}$ and $\Phi(\omega^{(0)}) = 0$, and expanding $\Phi(\omega)$ near frequency $\omega^{(0)}$, we find:

$$\varepsilon = iA(\omega^{(0)})(\partial\Phi/\partial\omega^{(0)})^{-1}. \tag{7}$$

The change in the amplitude of the wave with altitude as it is propagated along the magnetic field in the ionosphere we find in a geometrical optics approximation [5]. This is permissible, since the wavelength λ is much less than ℓ, the characteristic scale at which the concentration changes markedly (at altitude $h \sim 600$ km and $\omega \sim 3 \cdot 10^3\ s^{-1}$, $\lambda \sim 2$ km). The amplitude of the wave is proportional to:

$$b \infty n^{1/2} \exp\left(-\frac{\omega}{c}\int_{h_0}^{h} \varkappa\, dz\right) = n^{1/2} e^{-\gamma}, \tag{8}$$

where from (5) and (7)

$$n = (\omega_{0e}^2/\omega\omega_{He})^{1/2}, \quad \varkappa = \varepsilon/v_{\text{гр}}, \quad v_{\text{гр}} = \partial\omega/\partial k. \tag{9}$$

Here v_{gr} is the group velocity of the waves. The ratio of radiation levels, for example, at h_0 = 300 and 800 km, equals:

$$\eta = \frac{b^2(300\ \text{км})}{b^2(800\ \text{км})} = \frac{n(300\ \text{км})}{n(800\ \text{км})} e^{\gamma}. \tag{10}$$

From (5), (7) and (9) we find:

$$\gamma \approx 10^{-16}\omega^{1/2}. \tag{11}$$

Utilizing the averaged model of a daytime ionosphere (table 1), as the result of numerical integration in (8) from h_0 = 300 km to h = 800 km we find that at a frequency of f_1 = 0.5 kHz, $\gamma_1 \approx 0.5$ and at f_2 = 2.5 kHz, $\gamma_2 \approx 1$.

Consequently, the ratio of radiation levels at h = 300 and 800 km for f = = 0.5 kHz is:

$$\eta \approx [N_e(300\ \text{км})/N_e(800\ \text{км})]^{1/4} e^{\gamma_1} \approx 10. \tag{12}$$

In computing (12) it was taken into account that in the altitude range selected N_e is diminished about 16-fold (table 1).

Thus, the intensity of radiation at f_1 = 0.5 kHz in propagation of a wave upward along the path considered is diminished by approximately 10 dB, which agrees satisfactorily with the experiment. The same effect should have been observed also at f_2 = 2.5 kHz. The absence of an altitude dependence in the latter instance is apparently related to the fact that this radiation arrives from above and the increase in amplitude resulting from an increase in the concentration of cold plasma electrons (reduction in the rate of propagation of the wave) is compensated by absorption.

Qualitative Discussion of Ionospheric Generation

Equation (3) makes it possible also to study the excitation of electromagnetic radiation, for which it is necessary to know the distribution function of energetic particles in the generation region. But at the present time there are no sufficiently reliable experimental data on the distribution function at ionospheric altitudes at mid-latitudes. Recalculating equatorial measurements by employing the Liouville theorem seems unjustified to us [7]. The fact is that pitch-angle diffusion exerts a considerable influence on the distribution function of particles whose velocities lie near the cone of loss, and of quasi-captured electrons and protons in particular. In this case this theorem is invalid.

In view of the above, we cannot give strict consideration to questions of generation. But this is of fundamental importance for the hypothesis advanced regarding the ionospheric origin of a considerable percentage of the ELF radiation observed at low altitudes. The fact is that, as follows from the preceding, there exists in the ionosphere pronounced absorption of waves, the effective number of collisions is rather high (cf. table 1), and in principle the excitation of waves can be suppressed by collisions. We have given consideration to the influence of collisions on the possibility of generation by employing the model function

$$F_s = \frac{N_s}{4\pi(l+1)!} \frac{v_\rho^l e^{-v_\rho/v_\rho^*}}{(v_\rho^*)^{l+2}} [\delta(v_z - v_s) + \delta(v_z + v_s)], \tag{13}$$

where v_z is velocity along the magnetic field of Earth; v_ρ is the transverse velocity; $v_\rho^* = v_\rho^{max}/\ell$; v_ρ^{max} is the velocity arrived at by the maximum in the distribution of energetic particles, and concentration N_s was assumed to be close to that experimentally observed. A certain basis for choosing (13) was provided by the fact that at ionospheric altitudes during the magnetically quiet period streams of captured and quasi-captured particles essentially prevail over poured-out and reflected streams; consequently the distribution function at the ends of the magnetosphere's magnetic trap has a distinctly marked maximum at pitch angles close to $\pi/2$.

Substituting distribution function (13) in (4), and integrating, we find:

$$\Delta = \delta[(kv_s - \omega \mp \omega_{B\alpha})^{-2} + (\omega - kv_s \pm \omega_{B\alpha})^{-2}],$$
$$\delta = \omega_{0e,n}^2 (l+3)(l+2) k^2 v_\rho^{*2} / 4\omega^2. \tag{14}$$

In the reduced expression the superscript refers to the proton flux ($\alpha = p$) and the subscript to electrons ($\alpha = e$).

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Since the concentration of energetic particles is low, their contribution, of course, is considerable in the region of frequencies ω at which one of the round brackets in (14) is close to zero, i.e., the kinematic conditions for cyclotron resonance are fulfilled. Let us consider first the generation of waves by protons traveling toward Earth. In this case, in a zeroth-order approximation ($\omega^{(0)}$ and k are real), from

$$kv_0 - \omega^{(0)} - \omega_{Bp} = 0 \tag{15}$$

and the dispersion equation without taking absorption into account,

$$c^2k^2/\omega^{(0)2} = \omega_{0e}^2/\omega^{(0)}\omega_{Be} \tag{16}$$

we find the frequencies satisfying the necessary radiation condition:

$$\frac{\omega^{(0)}}{\omega_{Bp}} = 1 + \frac{v_0^2\omega_{0e}^2}{2c^2\omega_{Be}\omega_{Bp}} \pm \left[\frac{v_0^2\omega_{0e}^2}{c^2\omega_{Be}\omega_{Bp}} + \frac{1}{4}\left(\frac{v_0^2\omega_{0e}^2}{c^2\omega_{Be}\omega_{Bp}}\right)^2\right]^{1/2}. \tag{17}$$

Assuming that $\omega_{0e}^2 \approx 6\cdot10^{15}\ s^{-2}$ and $\omega_{Be} \approx 6\cdot10^6\ s^{-1}$, at an altitude of $h = 300$ km from (17) we find, for example, when $v_0 = 0$, $\omega^{(0)} = \omega_{Bp}$ ($f = 0.5$ kHz), and when $v_0 \approx 3\cdot10^7\ cm\cdot s^{-1}$, $\omega_1^{(0)} \approx 5\,\omega_{Bp}$ ($f \approx 2.5$ kHz) and $\omega_2^{(0)} \approx 0.2\,\omega_{Bp}$ ($f \approx 100$ kHz). For the purpose of finding the addition to $\omega^{(0)}$ causing the generation (or absorption) of radiowaves, μ, on the assumption that $|\mu| \ll |\omega^{(0)}|$, as above we will use the method of disturbances (cf. also [8]). Then, by taking dissipation into account, we get:

$$\mu = a\omega^{(0)1/2} - b\omega^{(0)}, \tag{18}$$

where

$$a = \frac{\sqrt{3}}{2}\left[\frac{(l+2)(l+3)}{4l^2}\,\omega_{0e}^2\left(\frac{v_p^{max}}{c}\right)^2\right]^{1/2}, \quad b = \frac{\nu_e}{2\omega_{Be}}. \tag{19}$$

It is obvious from (1) that $\mu > 0$ (generation, amplification) in the frequency band

$$0 \leqslant f \leqslant (a/b)^{2}. \tag{20}$$

For the purpose of finding the order of magnitude of μ we use the experimental data. For example, according to [9], protons with energy of $E_p \approx 0.3$ to 0.4 MeV, at $L \approx 2.5$ and $B_0 \approx 0.3$ gauss, have a concentration of

$N_{sp} \sim 3 \cdot 10^{-5}$ cm^{-3} (at $h \lesssim 400$ km these drift tracks descend near the Brazilian anomaly). Assuming that $v_e \sim 1.5 \cdot 10^3$ s^{-1}, from (17) to (19), and with $\ell = 2$, we find: μ ($f = 0.5$ kHz) ~ 4 s^{-1}.

Nonrelativistic electrons cannot satisfy condition (15) in the range of ELF radiation frequencies. For relativistic electrons, with $\omega \ll \omega_{Be}$, $kv_0 \gg \omega$, the resonance frequency and increment, respectively, equal:

$$\omega = \frac{\omega_{Be}^3}{\omega_{0e}^2}\left(\frac{c}{v_0}\right)^2\left(\frac{m_0c^2}{E_k+m_0c^2}\right)^2, \tag{21}$$

$$\mu = \frac{\sqrt{3}}{2}\omega_{Be}\left(\frac{m_0c^2}{E_k+m_0c^2}\right)^{[illegible]}\left[\frac{N_{0s}(l+2)(l+3)}{N_0 4l^2}\left(\frac{v_{max}}{v_0}\right)^2\right]^{1/3} - b\omega. \tag{22}$$

Assuming, according to [10], that for electrons with $E_k = 1$ MeV, $N_{se} \sim 10^{-8}$ cm^{-3} ($L \sim 2.5$ and $B \sim 0.3$ gauss) and $v_0/c \sim 0.2$, we find: $f \gtrsim 8$ kHz and $\mu \sim 10^2$ s^{-1}.

Estimate of Radiation Intensity

We will make a non-strict and rather rough estimate of radiation intensity in the following manner.

The energy radiated by a single particle per second in a magnetic field equals [3]

$$P_{1s} \approx (2/3)(e^2/c^3)nd^2, \tag{23}$$

where $d = v_\perp \omega_{Bs}$ is the acceleration; ω_{Bs} and $v_\perp$ are the gyrofrequency and velocity component of a particle perpendicular to Earth's magnetic field; e is the charge; and n is the refractive index of the medium.

The flux density of the radiation energy of particles with a concentration of N_s in a volume with a cross sectional area of 1 cm^2 and length ℓ along the magnetic field will be

$$P = N_s P_{1s} l. \tag{24}$$

Then the spectral flux density of the radiation energy is

$$S = P/\Delta f. \tag{25}$$

The radiation band, Δf, can be found, for example, from the change in the gyrofrequency, ω_{Bs}, during movement along the magnetic field for a distance of ℓ:

$$\Delta f = \frac{\Delta\omega_{Bs}}{2\pi} = \frac{l}{2\pi m_a}\Delta B \simeq \frac{3\omega_{Bs}}{2\pi}\frac{l}{R_s}. \tag{26}$$

Assuming for protons the values of $\ell \approx 100$ km, $\omega_{Bp} \approx 3\cdot10^{3}\ s^{-1}$, $n \approx 3\cdot10^{2}$, $E_I \approx 1$ MeV, $N_{sp} \approx 3\cdot10^{-5}\ cm^{-3}$ [9], we get for the incoherent radiation:

$S = 5\cdot10^{-}$[illegible] W/m^2Hz.

If it is assumed that in a volume λ^3 particles radiate coherently, then the flux density of the radiation energy equals:

$$P \approx (N_s\lambda^3)^2 P_1. \tag{27}$$

The flux density of the radiation energy of a volume with a 1-cm^2 cross section and length ℓ equals:

$S = \frac{P}{\lambda^3 \Delta f}\frac{l}{\lambda} \leqslant (10^{-}$[illegible] to 10^{-}[illegible]$)$ W/m^2Hz

which approximates the radiation level observed in the experiment in [2]. Coherent Cherenkov radiation gives the same in terms of order of magnitude.

Bibliography

1. Jiřiček, F. et al. STUDIA GEOPHYS. ET GEOD., 1973, 17, 43.

2. Vakulov, P.V., Dobrovol'ska, B., Zakharov, A.V., Kovner, M.S., Kuznetsov, S.N., Kuznetsova, V.A., Larkina, V.I. and Likhter, Ya.I. PIS'MA V ZHETF, 1975, 22, 441.

3. Eydman, V.Ya. ZHETF, 1958, 34, 131.

4. Kovner, M.S. IZV. VUZOV, RADIOFIZIKA, 1960, 3, 631, 746.

5. Ginzburg, V.L. "Rasprostraneniye elektromagnitnykh voln v plazme" [Propagation of Electromagnetic Waves in Plasma], Nauka, 1967.

6. Gurevich, A.V. and Shvartsburg, A.B. "Nelineynaya teoriya rasprostraneniya radiovolny v ionosfere" [Nonlinear Theory of Radiowave Propagation in the Ionosphere], Nauka, 1973.

7. Molchanov, O.A., Reznikov, A.Ye. and Fligel', D.S. GEOMAGNETIZM I AERONOMIYA, 1976, 16, 1123.

8. Kovner, M.S. ZHETF, 1962, 32, 147.

9. Nihatov, J.D. and White, R.S. J. GEOPHYS. RES., 1966, 71, 2207.

10. Vakulov, P.V., Vorob'yev, V.A., Kuznetsov, S.N., Logachev, Yu.I., Savenko, I.A. and Stolpovskiy, V.G. KOSMICHESKIYE ISSLEDOVANIYA, 1975, 13, 945.

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MECHANISMS OF MAGNETOSPHERIC PROPAGATION OF SHORTWAVE SIGNALS

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[Text] A theoretical discussion is presented, of a possible mechanism for the propagation of a magnetospheric shortwave signal, related to the refraction of waves at electron concentration gradients. Estimates are given for the lag in the ionosphere (to altitudes of 1500 km) and in the magnetosphere.

The possibility of magnetospheric propagation of shortwave radiowaves has already been indicated recently (cf., e.g., [1]). In recent times a number of experimental data have appeared in print, confirming the possibility of magnetospheric propagation of shortwave signals between magnetically linked ground points [2-4]. In connection with this, it seems opportune to make a more detailed investigation of the different probable mechanisms for the propagation of magnetospheric SW signals. In this paper estimates are made of the lag of these signals in the magnetosphere or when they are crossing the ionosphere, and also discussed is refraction of a magnetospheric signal. Calculations are made as applied to experiments in the transmission of signals between the European sector of the USSR and magnetically linked areas in the Indian Ocean [4]. Consideration is given to the propagation of signals in strata of the ionosphere, to magnetospheric propagation of the whistler mode type, and to the channeling of signals in inhomogeneities with reduced ionization density. Cases of the appearance of paired signals are discussed.

1. Let us estimate the time for signal lag and beam refraction in the propagation of waves in the ionosphere. By ionosphere here is meant the region in which the refractive index of the SW signal differs considerably from unity and at the boundary of which the beam is "fastened to" a line of force of the geomagnetic field. In the calculations the thickness of the ionosphere is conventionally assumed to equal 1500 km. For the purpose of estimates of signal lag time a lack of strictness in determination of the thickness of the ionosphere is not important. It is only necessary that the upper limit of the

ionosphere lie in a region where the plasma frequency of the medium is low as compared with the frequency of the signal ($\omega_0 < \omega$), and it is possible to disregard the influence of refraction.

We will utilize a model of a plane single-layer ionosphere; the electron density, N , to the maximum of the F layer is described by a parabola, and above this by the transition layer law (fig 1):

$$N = N_0\{1-[(y-h)/h]^2\} \text{ with } 0<y<h, \quad (1)$$

$$N = N_0 4\exp[\gamma(y-h)]/\{\exp[\gamma(y-h)]-1\}^2 \text{ with } h<y<y_m, \quad (2)$$

where h is the half-thickness of the layer, i.e., the distance from the lower limit to the layer's maximum; N_0 is the value of the concentration at the maximum; γ is a parameter characterizing the thickness of the transition layer; y_m is the thickness of the ionosphere, i.e., the distance from the lower to the conventional upper limit of the layer; and H is the height of the lower limit of the layer.

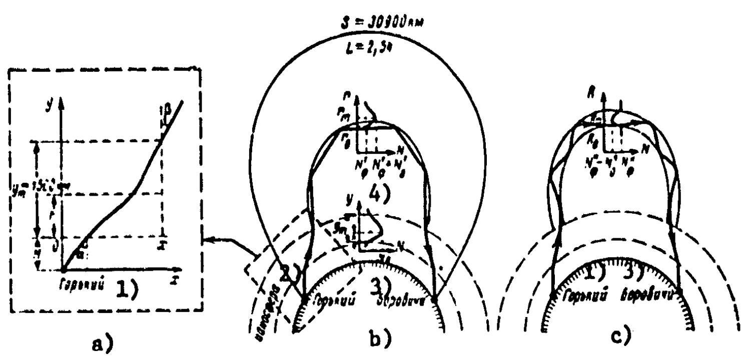

Figure 1.

Key:
1. Gor'kiy
2. Ionosphere
3. Borovichi
4. N_f'

The dielectric constant of the plasma [5] is:

$$\varepsilon = 1-\omega_0^2/\omega^2 = 1-\frac{8{,}06\cdot10^7 N(y)}{f^2}, \quad (3)$$

where $f = \omega/2\pi$ is the operating frequency. From the eikonal equation, $n^2 - \varepsilon(y) = 0$ (here $n = \nabla\phi$, where ϕ is the characteristic function), in taking into account the Snellius law for a plane-layered medium (propagation of the signal takes place in plane x,y), it follows that:

$$n_x = n_0 \sin\alpha = \sin\alpha, \tag{4}$$

where α is the angle of entry of the beam into the ionosphere; n_0 is the value of n below the ionosphere, and

$$n_y^2 = \cos^2\alpha - \zeta[1-(y-h)^2/h^2]N_0 \text{ with } 0 \leq y \leq h, \tag{5}$$

$$n_y^2 = \cos^2\alpha - \zeta 4e^{\gamma(y-h)}N_0/[e^{\gamma(y-h)}+1]^2 \text{ with } h \leq y \leq y_m, \tag{6}$$

where $\zeta = 8.06 \cdot 10^7/f^2$.

We are interested in angles α with which a beam, having left Earth, can travel into the region above the layer's maximum, i.e., $0 \leq \alpha < \alpha_{kr}$; where $\alpha_{kr} = \arccos\sqrt{\zeta N_0}$ is the critical angle of incidence of the beam onto the ionosphere, beginning with which a signal of a specific frequency, reflected from the ionosphere, returns to Earth. Then for horizontal movement of the beam in the ionosphere, x (along the surface of Earth), the combined delay time, t , and angle β at which the beam reaches the upper limit of the ionosphere, we have:

$$x = \sin\alpha\left[\frac{H}{\cos\alpha} + \frac{1}{\sqrt{A}}\ln\frac{2\sqrt{Ar_1}+2Ah+B}{2\cos\alpha\sqrt{A}+B} + \frac{1}{\gamma\sqrt{C}}\ln\frac{(2\sqrt{CS}+2Cu+B_1)u}{(2\sqrt{CS}+B_1u+2C)}\right], \tag{7}$$

where

$$t = \frac{x}{3 \cdot 10^8 \sin\alpha}, \quad \beta = \arcsin\frac{\sin\alpha}{n},$$

$$n = [1 - 4\zeta N_0 u/(1+u)^2]^{1/2}, \quad u = \exp[\gamma(y_m - h)],$$
$$S = C(u^2+1) + 2(C - 2\zeta N_0)u, \quad r_1 = \cos^2\alpha - \zeta N_0,$$
$$A = \zeta N_0/h^2, \quad B = -2\zeta N_0/h, \quad C = \cos^2\alpha,$$
$$B_1 = 2(C - 2\zeta N_0).$$

For the purpose of computing x , t and β it is necessary to assign the specific parameters entering into the model of the ionosphere. As an example, in table 1 are given the results for the experiments described in [4], conducted in the fall of 1970 and 1974. Emission took place in Gor'kiy, and reception at a magnetically linked point in the Indian Ocean on the NIS [scientific research vessel] "Borovichi." Therefore, as the raw data for the ionosphere below the maximum of the F2 layer were used Nh profiles computed from ionograms from vertical probing in Gor'kiy and on the "Borovichi." In the table are given the values of parameters H , h and N_0 . Magnetospheric signals were registered usually in the morning and evening hours, close to the moments of sunrise and sunset. Therefore, the values of H , h and N_0 indicated in the table relate to these periods of the day. With low solar activity (1974), the E layer is usually not observed in the early morning and late evening hours in October; therefore, the lower edge of the F2 layer (H = 220 km) was taken as the lower limit of the ionosphere. A well marked E layer is observed in the morning and evening hours of the day with high solar activity (1970). Therefore, its altitude was taken as the lower limit of the ionosphere.

Table 1.

1) t, час	$H=220$ км, $h=66$ км, $N_0=1{,}7\cdot10^5$ см$^{-3}$, $\gamma=-4{,}12\cdot10^{-3}$						$H=100$ км, $h=200$ км, $N_0=5{,}4\cdot10^5$ см$^{-3}$, $\gamma=-3{,}95\cdot10^{-3}$					
	2) Период минимума солнечной активности						3) Период максимума солнечной активности					
	4) $\alpha_{кр}$	α	5) t, мсек	x, км	β	90° − I	$\alpha_{кр}$	α	t, мсек	x, км	β	90° − I
4	22,2°	19,3 7,9	6,13 5,71	611 237	19,4 7,95	23,5						
5	42	36,3 13,5	7,25 5,93	1300 418	36,4 13,5	30						
6	51,6	40,3 17,4	7,79 6,17	1515 557	40,4 17,4	31						
7	58	40,7 23,6	7,93 6,52	1556 786	40,8 23,6	32	19,4°	13,7 8,0	6,01 5,75	430 242	13,8 8,1	22
8	62,2	45 27,9	8,6 6,8	1833 965	45,1 27,9	35	34,2	28,6 17,2	6,57 5,80	947 516	28,7 17,2	27
9	65,3	48,3 31,2	9,22 7,13	2072 1112	48,4 31,2	38	42,6	31,2 19,8	6,60 5,88	1032 602	31,3 19,8	28
10	68	47,2 33,7	9,77 7,38	2282 1234	47,2 33,7	40,5	48,5	31,4 14,2	6.68 5,71	1033 425	31,4 14,2	28
11	73	58,6 35,8	11,96 7,60	3071 1339	58,6 35,8	51,5	52,9	35,8 18,7	6,98 5,89	1229 669	35,8 18,7	29,5
12	74,5	60,2 37,4	12,62 7,80	3299 1429	60,2 37,4	54,5	56,3	33,5 10,7	6,80 5,71	1132 321	33,6 10,7	29,5
13							59	47,7 25,0	8,63 6,24	1926 795	47,7 25,0	35,5
14							61,6	44,4 27,3	8,08 6,41	1704 888	44,4 27,3	34

[Key on following page]

Key:

1. f, MHz
2. Period of minimum solar activity
3. Period of maximum solar activity
4. α_{kr}
5. t, ms

Since there were no data on the state of the upper ionosphere in the necessary regions during the periods of recording magnetospheric signals, data from outer-space probes were sampled, corresponding to the same solar and magnetic activity, at points with the necessary latitude, but with a considerable difference with regard to longitude. In the table are indicated values of γ determined from equation (2), for Nh profiles obtained with an ISZ [artificial Earth satellite] [6]. In the table are presented values of $\alpha_{kr} = \arccos \sqrt{\zeta N_0}$ computed for the 4 to 14 MHz frequency band, and values of t, x and β computed from equations (7) for randomly selected angles of $\alpha < \alpha_{kr}$. In the 90°-I columns are given the differences between 90° and the angles of magnetic dip at the respective geographical points (with coordinates of x, y_m; cf. fig 1a). This is necessary since the optimal condition for the capture in a magnetospheric waveguide of shortwave signals leaving the ionosphere is closeness of the direction of the outgoing signal and the direction of the line of force of the magnetic field (cf. below).

2. Let us consider mechanisms for the channeling of waves in the magnetosphere and the conditions under which an SW signal can arrive along a magnetospheric path at a magnetically linked point. Two of these mechanisms are probably possible [1,7]: the whistler mode type (reflection from inhomogeneities with an elevated electron concentration, stretching along lines of force), and direct ducting (inside inhomogeneities with a lowered concentration, stretching along the field). This hypothesis can be verified if it is assumed that a magnetospheric signal is related to predawn and postsunset effects. A collisionless sonic wave is propagated in the magnetosphere at this time along tubes of force. It can "sweep out" electrons from a tube, at the boundary of which a layer with an elevated electron concentration is created [4]. Electron concentration gradients perpendicular to the axis of a tube, that is, can make possible intermittent propagation of waves of the whistler type, or ducting.

The discussion of propagation mechanisms in this paper is of a semi-qualitative nature, and its main objective is to determine the physical criteria resulting in the guiding of SW signals. Calculations have been made for the two-dimensional problem, using a spherical laminar medium as an example. Let us note that taking the dipole nature of the geomagnetic field into account does not lead to qualitatively new results if attention is not paid to gradients of electron concentration along lines of force. This can be done easily adiabatically, or by very simply dividing the path into a number of pieces with their own local radii of curvature, or, taking into account the slowness of the change in properties along a line of force, by utilizing the adiabatic invariant (similarly to [8]).

In order for whistler mode propagation to be possible, there must exist in the direction perpendicular to the lines of force of the geomagnetic field a unilateral drop in electron concentration, resulting in lowering of the refractive index (cf. fig 1b). Assuming for the sake of simplicity that the lines of force of the geomagnetic field represent parts of a circle, we assume that the electron concentration varies according to the following law:

$$N'(r)=N_f'+N_0'\left[1-\left(\frac{r-r_m}{r_m-r_0}\right)^2\frac{r_0^2}{r^2}\right] \text{ with } r_0<r<r_m,$$
$$N'(r)=N_f' \qquad \text{with } r<r_0, \tag{8}$$

where N_f' is the background electron concentration.

Since the discussion will be conducted for the reflection of waves from a wall in the region of $r_0 < r < r_m$, the behavior of $N'(r)$ when $r > r_m$ is not important, and therefore no conditions are imposed on the shape of $N'(r)$ in the region of $r > r_m$. Thus, it is assumed that in a homogeneous plasma with a background concentration of N_f' there exists a "blurred plasma wall" with an electron concentration drop of N_0' and a half-thickness of r_m. This distribution for $N'(r)$ can be related to the existence of global concentration inhomogeneities having a gradient perpendicular to the lines of force of the geomagnetic field.

From the eikonal equation, which in this case has the form

$$(\partial\varphi/\partial r)^2+r^{-2}(\partial\varphi/\partial\theta)^2-\varepsilon(r)=0, \tag{9}$$

taking into account the Snellius law for a spherical laminar medium we have

$$n_r^2=1-\zeta N'-b^2/r^2, \tag{10}$$

where the integration constant for $b^2 = n_\theta^2 r^2$ is determined by the equation

$$b=r_s\sqrt{1-\zeta(N_f'+N_0')},$$

where r_s is the radius of the sphere from which the beam departs, at an angle of $\delta = \pi/2$ to the direction of the electron concentration gradient.

Let at some point of origin of $r_s, \theta = 0$ the beam depart perpendicular to the direction of the electron concentration gradient ($\delta = \pi/2$). It refracts in the layer and returns to the same altitude at the same angle of $\pi/2$ (since the model is spherical laminar). If there is a concentration gradient along the "wall" (dependence $N(\theta)$), ducting conditions can be improved or worsened. For example, if dependence $N(\theta)$ has a negative gradient along the line of signal propagation, then angle $\delta = \pi/2$ will be achieved with values of $r > r_s$ and we have an improvement in ducting conditions. But if the gradient of dependence $N(\theta)$ is positive, then ducting conditions are worsened.

From the equation for the beam for our model we get the angular distance traveled by the beam in a single step, i.e., the minimum angular distance between two successive points:

$$\theta = -\frac{r_m\sqrt{1-\zeta N_\Phi'}}{\sqrt{C}}\ln\frac{(B^2-4AC)r_0^2}{(2\eta\sqrt{C}+Br_0+2C)^2}+2\arccos\frac{r_s}{r_0}, \tag{11}$$

where

$$A=1-\zeta N_\Phi'-\zeta N_0'(1-r_0^2/z_m^2),\ B=-2(r_m^2r_0^2/z_m^2)\zeta N_0',$$
$$C=\zeta N_0'r_m^2r_0^2/z_m^2-r_s^2(1-\zeta N_\Phi'),\ \eta=\sqrt{(r_0^2-r_s^2)k},\ k=1-\zeta N_\Phi'.$$

Here it is assumed that $r_s > r_0$ and from the condition r_{otr} [radius of reflection] $> r_0$, i.e.,

$$r_{\text{отр}}=\frac{-B-\sqrt{B^2-4AC}}{2A}>r_0, \tag{12}$$

is gotten the condition for the maximum possible width of the duct with specific N_0'/N_f', r_0 and N_f':

$$z_m\leqslant N_0'r_0/[1-\zeta(N_\Phi'+N_0')]. \tag{13}$$

The combined lag time for the signal in a single step equals

$$t_{\text{гр}}=\frac{1}{3\cdot10^5}\left\{\frac{2\eta}{k}\left(1-\frac{k}{A}\right)-\frac{B}{2A^{3/2}}\ln[(B^2-4AC)/(2\eta\sqrt{A}+2Ar_0+B^2)]\right\}. \tag{14}$$

It is obvious from (13) that with N_0'/N_f' = 1 to 10 percent, r_0 = 3 to $6\cdot10^3$ km, and $N_f' = 10^3$ to $6\cdot10^3$ cm^{-3} the maximum width of the duct, z_m, can vary from about 1 km to about 100 m. Furthermore, r_s differs very slightly from r_0. For example, with $N_f' = 6\cdot10^3$ cm^{-3} and $N_0'/N_f' = 0.06$, if $r_0 = 3\cdot10^3$ km and f = 7 MHz, then $z_{m\,max}$ = 1.8 km, z_m = 0.6 km and

$r_s = 2999.7$ km, we get $\theta_0 = 0.0445$ rad and $t_{gr} = 5.574 \cdot 10^{-4}$ s. The total number of steps, n, equals 96 and the total time, t_{poln}, equals $nt_{gr} \approx 54$ ms. If it is assumed that $r_0 = 6 \cdot 10^3$, $f = 7$ MHz, then $z_{n\,max} = 5.6$ km, $z_m = 0.6$ km and $r_s = 5999.7$ km, we get $\theta_0 = 0.0196$ rad and $t_{gr} = 0.00587$ s. In this case the total number of steps equals $n = 218$ and $t_{poln} = 127$ ms. For a line of force leaving the surface of Earth at a magnetic latitude of 50°, r_0 varies over the range of $(3 \text{ to } 6) \cdot 10^3$ km. Thus, with the parameters selected above the total combined lag time, t_{poln}, lies between 54 and 127 ms.

A more detailed analysis has shown that if it is assumed that $N_f' = 6 \cdot 10^3$ cm^{-3}, $N_0'/N_f' = 0.06$, then with a variation in frequency over the range of $5 \le f \le 9$ MHz and in z_m of from 0.5 to 1.1 km, with $r_0 = 3 \cdot 10^3$ km and $2999.6 \le r_s \le 2999.9$ km, t_{poln} lies within the range of $30 \le t_{poln} \le 80$ ms. If $r_0 = 6 \cdot 10^3$ km and $5999.6 \le r_s \le 5999.8$ km, then $60 \le t_{poln} \le 160$ ms.

3. Reflection from Two Walls (Ducting)

In this case as the model is used a homogeneous concentration, N_f'', against whose background there are concentration inhomogeneities stretching along the lines of force of the geomagnetic field, which vary according to a quasi-parabolic law (fig 1c):

$$N''(R) = N_\Phi'' - N_0''\left[1 - \left(\frac{R - R_m}{z_m}\right)^2 \frac{R_0^2}{R^2}\right]. \tag{15}$$

Let us consider a beam leaving a point located on the axis of the duct and reflected from the upper wall. For this beam the following inequalities must be fulfilled:

$$f > [8{,}06 \cdot 10^7 (N_\Phi'' - N_0'')]^{1/2},\ R_{отр} \le R_m R_0/(R_0 - z_m),\ \varkappa > \varkappa_{кр}, \tag{16}$$

$$\varkappa_{кр} \ge \arcsin \frac{R_0\sqrt{1 - \zeta N_\Phi''}}{(R_0 - z_m')\sqrt{1 - \zeta(N_\Phi'' - N_0'')}}. \tag{17}$$

From (16) is obtained the condition for the maximum possible width of the duct:

$$z_m' \le R_0\left(1 - \sqrt{1 - \zeta N_\Phi''}/\sqrt{1 - \zeta(N_\Phi'' - N_0'')}\right). \tag{18}$$

In considering reflection from the lower wall of the duct, an inequality is gotten for permissible angles κ which is slighter than (17). Therefore, in considering the total track the inequalities in (17) should be used.

The length of the path and the combined lag time at a single step are determined by the equations:

$$\theta_0 = \frac{b_1}{\sqrt{-C'}}\left[\frac{\pi}{2} + \arcsin\frac{2b_1^4}{R_m\sqrt{B'^2-4A'C'}}\right],$$

$$t_{\text{rp}} = -\frac{1}{3\cdot 10^5}\left\{\frac{R_m\sqrt{1-\zeta(N_\Phi''-N_0'')\cos\varkappa}}{A'} + \right.$$

$$\left. + \frac{B'}{2A'\sqrt{-A'}}\left[\frac{\pi}{2} + \arcsin 2R_m\frac{1-\zeta(N_\Phi''-N_0'')}{\sqrt{B'^2-4A'C'}}\right]\right\}, \qquad (19)$$

where

$$R_m = R_0 + z_m, \quad A' = 1-\zeta N_\Phi'' + \zeta N_0''(1-R_0^2/z_m^2),$$

$$B' = 2\zeta N_0''\frac{R_m^2R_0^2}{z_m^2}, \quad C' = -\zeta N_0''\frac{R_m^2R_0^2}{z_m^2} - b_1^2,$$

$$b_1 = R_m\sin\varkappa\sqrt{1-\zeta(N_\Phi''-N_0'')}.$$

When $N_0''/N_f'' = 0.02$, $N_f'' = 6\cdot 10^3\ \text{cm}^{-3}$ and $f = 6$ MHz, if $R_0 = 3\cdot 10^3$ km, we get $z_{m\,max} = 0.4$ km, and having assumed that $z_m = 0.3$ km, we have $\kappa_{kr} = 1.562$ rad and for $\kappa\in(\kappa_{kr}, \pi/2)$, $t_{gr} = 0.000476$ s and $\theta_0 = 0.0236$ rad. If $R_0 = 6\cdot 10^3$ km, we get $z_{m\,max} = 0.81$ km, having assumed that $z_m = 0.7$ km, we have $\kappa_{kr} = 1.565$ and for $\kappa\in(\kappa_{kr}, \pi/2)$, $t_{gr} = 0.001210$ s and $\theta_0 = 0.030$ rad.

As is obvious from the calculation results, the direction of propagation differs very slightly from the direction of the line of force of the magnetic field ($\kappa \sim \pi/2$). Thus it has been demonstrated that under certain conditions the propagation of SW signals along lines of force of the geomagnetic field is possible, when on account of refraction at electron concentration gradients perpendicular to H_0 (or almost perpendicular) the beam "turns down" and follows along the lines of force of the geomagnetic field.

4. In a magnetospheric SW signal magnetoionic splitting is usually observed [4]. The typical lag times of the second signal in relation to the first lie within the range of $\Delta t \sim 1$ to 3 ms, and several times $\Delta t \sim 10$ ms has been observed.

Two mechanisms are possible for the purpose of explaining this effect. If magnetoionic splitting is taken into account, the difference in the signals' lag times is determined by the equation:*

$$\Delta t = c^{-1} \int (1/n_1 - 1/n_2)\, dl, \tag{20}$$

where c is the speed of light in a vacuum, and the refractive indices of the ordinary and extraordinary modes are $n_{1,2} \approx 1 - v/2 \pm v\sqrt{u}\cos\alpha/2$, where $v = \omega_0^2/\omega^2$; $u = \omega_H^2/\omega^2$ and ω_H is the gyrofrequency. Taking into account in this equation that $v \ll 1$ and $v\sqrt{u} \ll 1$ and assuming that $\alpha = 0$ (the beam travels along line H_0), from (20) we get:

$$\Delta t \approx \int v\sqrt{u}\, dS/c. \tag{21}$$

By S can be understood the length of an individual line of force of the geomagnetic field. Taking into account the fact that for the latitude of Gor'kiy $S \approx 31{,}000$ km, from (21) it is easy to get $\Delta t = 1$ to 2 ms.

As the second mechanism let us consider the difference in the path of two beams in the ionosphere if the latter has a concave boundary section exposed to a directional pattern of finite width [9]. In this case, on account of the difference in path between two beams hitting the ionosphere from above with considerably different angles α, the lag, Δt, can be about 2 to 4 ms.

And so, lags between magnetospheric signals of about 1 to 2 ms can be explained fully by magnetoionic splitting (ordinary and extraordinary waves). Lags of up to 4 ms are explained by the relative delay of different beams in the ionosphere, which takes place when the finiteness of the directional pattern is taken into account. For the purpose of explaining lags of about 10 ms it is necessary to assume the existence in the region essential for the propagation of magnetospheric SW signals of several electron concentration maxima and minima, which result in the fact that signals travel along different tracks.

In this case it is possible to estimate the distance in the equatorial plane between individual lines of force. It turns out to be about 500 to 600 km. If this effect is related to the rising and setting effect, then these estimates can be considered also as estimates of the distance between two individual electron concentration maxima in the magnetosphere in the equatorial plane.

*On the assumption that the signals are propagated along the same or close tracks.

5. With the assumptions which we have made regarding the ionosphere, from the table it is possible to draw certain conclusions concerning the filling of magnetospheric ducts (regardless of the mechanism for keeping beams in these ducts):

a. Not all frequencies can be propagated along a magnetospheric path, since capture in a magnetospheric duct can take place only in the case when the beam's exit from the ionosphere is close to the direction of the geomagnetic field. During the period of minimum solar activity a signal can be captured by a magnetospheric duct beginning from 5 to 6 MHz, and during the period of maximum solar activity, from 8 to 9 MHz, since for the lower frequencies the direction of the geomagnetic field differs from the direction of the beam's exit from the ionosphere (bounding from below). In addition, low frequencies simply do not fill the duct, since it is rather narrow and they trigger the conditions of "criticality" of the waveguide for the wavelength which it can admit. Signals can be propagated along a magnetospheric path which are up to about 12 MHz during the period of minimum solar activity, and up to about 14 MHz (cf. equations (11) and (19)) during the period of maximum activity (upper limit). Higher frequencies will go out into outer space. Therefore, in the table the possible cases of magnetospheric signal propagation are isolated with a solid line. Let us note that certain variations are possible, depending on the state of disturbance of the magnetic field.

b. Lags in the ionosphere resulting from the difference of the refractive index from unity, as compared with when the signal has traveled the same path at the speed of light, lie within the range of about 0.9 to 0.6 ms, or (since a magnetospheric signal passes twice through the ionosphere) about 1.8 to 1.2 ms.

c. The horizontal movement of a beam along the surface of Earth is within the range of about 1300 to 3300 km for the period of minimum solar activity and about 940 to 1700 km for the period of maximum activity, which results in the possibility of a considerable difference in the length of the track, S_{KV}, from the length of a line of force of the geomagnetic field corresponding to the point at which a transmitter is located on the surface of Earth.

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Bibliography

1. Du Castel, F. COMPT. REND. ACAD. SCI. FRANCE, 1965, 261, 1057.

2. Benediktov, Ye.A., Ben'kova, N.P., Bukin, G.V., Berezin, Yu.M. et al. In "Voprosy rasprostraneniya korotkikh radiovoln" [Questions Relating to the Propagation of Short Radiowaves], Part II, IZMIRAN, 1973.

3. Bukin, G.V. and Molchanov, O.A. GEOMAGNETIZM I AERONOMIYA, 1976, 16, 287.

4. Bukin, G.V. GEOMAGNETIZM I AERONOMIYA, 1978, 18, 440.

5. Ginzburg, V.L. "Rastprostraneniye elektromagnitnykh voln v plazme" [Propagation of Electromagnetic Waves in Plasma], Nauka, 1967.

6. "Alouette 1. Ionospheric Data N(h)," 1963, Vol 4, No 1, Canada.

7. Bukin, G.V. and Perekhvatov, Yu.K. GEOMAGNETIZM I AERONOMIYA, 1972, 12, 421.

8. Borisov, N.D. and Gurevich, A.V. "Tezisy dokladov XI Vsesoyuz. konfer. po rasprostraneniyu radiovoln" [Theses of Papers at the 11th All-Union Conference on Radiowave Propagation], 4, Kazan', 1975, 79.

9. Gotsakova, L.S. and Yashin, Yu.Ya. IZV. VUZOV, RADIOFIZIKA, 1978, 21, 333.

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GEOPHYSICS, ASTRONOMY AND SPACE

SEISMOACOUSTIC METHODS IN MARINE ENGINEERING AND GEOLOGICAL SURVEYS

Moscow SEYSMOAKUSTICHESKIYE METODY V MORSKIKH INZHENERNO-GEOLOGICHESKIKH IZYSKANIYAKH in Russian 1977 pp 3-6, 53-61

[Foreword, introduction and Section 9 from book by A. S. Levin and V. L. Mirandov, Izdatel'stvo "Transport"]

[Text] Among the tasks posed to maritime transport in the "Main trends for development of the national economy of the USSR for 1976-1980," confirmed by the 25th CPSU Congress, an increase of the capacity of maritime ports primarily due to construction of specialized transloading complexes with piers having a total length of 5.3 km is provided. This requires a large volume of research work, a significant fraction of which is related to the use of seismoacoustic methods of investigations.

Seismoacoustics is a new branch of prospecting geophysics which has occupied one of the leading positions during the past decade in investigations of the sea and ocean bottom. Scientists, engineers-geophysicists, geologists, hydroengineers, pipeline builders, road builders, bridge builders and many other specialists are interested in the results of seismoacoustic profiling.

Moreover, there is as yet no monographic edition in the domestic literature, besides Ye. F. Dubrov's book [31], which has become a bibliographic rarity, in which one could find the answers to questions of interest to specialists of different fields.

This book is called upon to supplement this gap to a known degree.

The characteristic feature of the book is an outline of the theoretical material with respect to consideration of specific practical problems. Mathematical apparatus is used in analyzing the considered problems, usually without detailed computations, in a form suitable for engineering calculations. The derivations in the main sections of the paper are illustrated by clear results of investigations, photographs and practical examples.

In systematizing the main principles in this special field of science, which seismoacoustics is, it would be impossible to avoid an outline of data from adjacent fields: acoustics, seismics, geometric optics, the physics of piezocrystals and radio engineering which undoubtedly affected the nature and sequence of the outline.

The authors atte ed to reveal the principles related to excitation, propagation and recording of elastic pulses in water and bottom soils for practical use of these phenomena in engineering-geological investigations.

All the foregoing permits one to hope that the book brought to the attention of readers will be useful not only to a wide range of specialists directly involved in engineering surveys and geological investigations of the coastal zone of the sea, but also to representatives of related fields.

The material for the book was many years of experience of the authors and their colleagues, generalized in articles, official reports, reports and also the results of introducing the method into survey practice.

Chapters 1 and 4 and Sections 11, 12, 18 and 19 and also the Foreword and Introduction were written by A. S. Levin, Section 1 and Chapters 2 and 3 were written by V. L. Mirandov and Section 5 and the section on suppression of multiple waves were written by V. L. Mirandov and A. G. Dlugach.

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Introduction

Seismoacoustics (this field of geophysics is sometimes called geolocation) is a branch of science arising at the juncture of seismic prospecting and echo sounding which utilizes the theoretical and technical achievements of both these fields of knowledge and which is involved with study of the bottom structure of water basins by using specially generated acoustic pulses.

The specific nature of the requirements placed on a device for seismoacoustic profiling determines the need to develop special apparatus, methods and techniques of conducting investigations.

The seismoacoustic method is essentially a modification of sonar and seismic surveying and consists in the following. Elastic vibrations which reach the bottom and are partially reflected from it and which partially penetrate the soils and are reflected from the interface in this mass are excited in the water by means of a special source. The reflected signals are trapped by a detector -- a piezoarray -- and, reprocessed in a specific manner, are recorded in the form of a pulse sequence to some information carrier. This pulse sequence forms the seismoacoustic path.

The process is repeated cyclically. A sequence of paths, called an echogram or recording, and corresponding to the geological profile along the observation line, is formed as a result of repetition of the "excitation-recording" cycle. This is also continuous seismoacoustic profiling (NSP). An insignificant fraction of energy reaches the reflecting boundaries during propagation of the pulse in the water and bottom soils; the pulse intensity drops as the distance from the excitation source increases.

Passage of acoustic pulses through the water and soils is related to three main phenomena which in the final analysis determine depth and detail* (resolution) of the method used in the investigations: 1) expansion of the pulse (wave) front, 2) absorption of elastic vibrations and 3) reflection of them from the interfaces. Of the enumerated factors, the favorable or in any case that used in seismic prospecting is only one -- reflection. The two others determine losses during pulse propagation and they are essentially different in nature. Expansion of the wave front is determined only by the length of the path of travel and is not dependent on the pulse spectrum, while absorption of elastic energy in the soils mainly depends on frequency.

Engineering surveys for construction of hydroengineering complexes are usually carried out in the coastal zone of the sea, the geological profile of which can be represented simply by three media: water, loose deposits and bedrock. One of the main problems faced by seismoacoustics is mapping the roof of bedrock under the layer of detritus. This problem is solved by the reflected wave method, i.e., by recording the shape and travel time of pulses reflected from the investigated boundary. Since they are recorded during motion of a ship, the noise related both to the motion of the ship and to purely physical factors of the medium are also recorded simultaneously with the useful signals.

The complexity and high cost of modern hydroengineering complexes require especially careful surveys: they are carried out at depths (in the soil) of 20-30 m and in this case the error of tying the determined boundaries by depth should not be greater than 2-3 percent, while resolution should provide separation of strata of minimum thickness (approximately 1 m) in the profile. These conditions in turn place rigid technical requirements on the apparatus and method of observations.

A special apparatus was developed during development of the seismoacoustic method for excitation and recording of elastic vibrations and special methodical procedures of using it were also developed. The echogram obtained as a result of seismoacoustic profiling is a geological profile in a distorted vertical scale. The distortions are explained by the fact that, beginning work, the investigator usually does not have sufficient data on the propagation velocities of elastic waves in soils. The field echograms should be reconstructed and presented to geologists in the form of a schematic acoustic-geological profile. The useful waves must be separated and the interference waves must be excluded on the echogram for this. The useful waves must be tied in to lithological boundaries so that the vertical scale of the profile corresponds in the final analysis to the real profile.

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*Depth is understood as the possibility of studying the profile to some specific depth and detail is understood as the capability of separating layers of given minimum thickness in the profile.

An entire complex of problems related to the use of seismoacoustics for solving engineering-geological problems in the coastal zone of the sea is considered in the book.

9. Receiving Devices

The receiving devices used in marine seismoacoustic surveys usually consists of the following main components: the receiver itself which converts elastic vibrations to an electric signals, a liquid-filled (castor oil or diesel fuel) protective housing, a preamplifier of weak signals occurring in the receivers, for confident transmission of them to the ship or a matching transformer and connecting cable.

Piezoelectric and magnetostriction pressure transducers were used most extensively as detectors. Piezoelectric materials for marine operations have been manufactured during the past few years primarily from various types of special piezoceramics. The main advantages of piezoceramics is the relatively low cost, low dependence of parameters on temperature, hygroscopicity, mechanical strength, good sensitivity and the possibility of creating detectors of any shape. Lead zirconate-titanate (TsTS) is mainly used in modern detectors among the many varieties of ceramics in Soviet and foreign apparatus [20]. The main properties of TsTS ceramics vary by less than 2-3 percent in the working temperature interval. The properties of TsTS vary by not more than 2-5 percent when using an external voltage in the range from 10^5 to 10^7 N/m^2 (i.e., when a piezoceramic element is submerged from sea level to a depth up to 100 m).

We note that the stability of piezoceramic properties is achieved only by conducting special "aging" procedures contained in the manufacturing process at the plant. Phenomena similar to aging, i.e., gradual variation of the properties of detectors, are also sometimes observed during very prolonged storage (up to several years) due to the effect of a number of factors (the effect of which has not been finally determined).

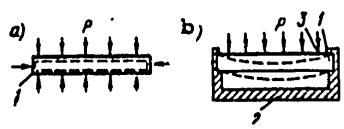

Figure 11. Diagrams of Sensing Elements of Detectors Operating on the Principle of Universal Compression (a) and Bending Deformations (b). The dashed line shows the contours of the piezoelement under the effects of pressure P: 1 -- piezoelement; 2 -- incompressible housing; 3 -- membrane

Detector designs whose sensing elements operate in either universal compression (Figure 11, a) or in bending deformation (Figure 11, b) modes are distinguished by working principle. Cylinders, plates, disks and other components of TsTS without finished design are related to "pure" detectors in which the principle of universal compression is realized. Bending type detectors are manufactured of flat sensing elements reinforced on the ends or edges and only one side of the sensing element protected by a membrane, comes into contact with the medium and air is located on the other side. These principal differences in designs also determine the sharp differences in sensitivity to pressure. The fact is that an electric space charge occurring on the edges of a piezoelement is proportional to its deformation due to the effect of external forces. Deformation of a bending detector (see Figure 11, b) due to the effect of the same pressure may obviously be significantly greater than that of a detector with an element operating in the universal compression mode.

The disadvantages of detectors operating by the bending deformation principle include appreciably higher cost and significant dependence on the depth of submersion [67]. The latter disadvantage has now been overcome abroad in some types of detectors. The efficiency of bending detectors due to maximum permissible bending of the membrane is retained at depths up to 100 m, whereas special designs of universal compression detectors [111] remain efficient at depths of several kilometers.

Detectors whose sensing element is a hollow TsTS cylinder, to the ends of whivh are attached sealed plugs of a nonconducting material, are used extensively in practice. Although slight bending deformations are inherent to this design, they are classified in the literature as universal compression detectors. Besides the cylindrical detectors, various designs operating in bending deformations are rather widely distributed, mainly abroad.

The main parameters of piezodetectors include sensitivity γ_r, i.e., the ratio of the electromotive force (e.m.f.) E on the detector terminals to the pressure applied to the detector; the natural capacitance and vibrational sensitivity, i.e., the ratio of e.m.f. on the terminals to variable accelerations occurring when the detector is towed in the water.

The sensitivity of detectors is a complex function of the frequency of perceived vibrations. The fact is that a detector is a vibrating mechanical system with its own resonance frequencies at which its sensitivity is maximum. Counting from the zero frequency axis, the first maximum frequency characteristic for a cylindrical element with radius R_{sr} is determined by the expression [6]

$$f_0 = \frac{\sqrt{E/\rho}}{2\pi R_{cp}} = c_\kappa/2\pi R_{cp},$$

where s_k is the speed of sound in ceramics.

This resonance corresponds to that of the radial vibrations of the cylinder and subsequent resonance frequencies are located in the range above f_0. Cylinders with radius on the order of 1-2 cm, for which the speed

$s_k = (3.5\text{-}4)10^3$ m/s, are used in serially manufactured piezodetectors. Then, on the basis of the given expression, $f_0 \gg 35$ kHz. With regard to the attaching elements and the effect of the reduced mass of the surrounding medium, the real resonance frequencies may differ significantly from that indicated, but they are always appreciably higher than the recorded range of frequencies during all operations by the continuous profiling method using electric-spark emitters. The resolving value for the frequency characteristic in the low-frequency band has natural capacitance of the detector and the input characteristics of the amplifiers and the transmitting cable.

The effect of the vibrational sensitivity of piezodetectors on the quality of continuous profiling materials was more distinctly determined rather recently during detailed investigations of the noise caused by towing the receiving devices in water [67]. It was established during the investigations that the horizontal components of vibrations are most significant. Jerking of the tow rope (cable) causes accelerated motions of the detectors in the medium, which leads to variation of pressures to different parts of the detectors and to the appearance of emf. Calculations and measurements [67] show that the noise level reaches 35-1,000 μV at real accelerations of 1-30 cm/s^2 for cylindrical elements used in marine piezoceramics and the vibrational sensitivity is hardly dependent on frequency in the frequency band from 20 to 1,000 Hz for domestic detectors. All things being equal, the ratio of pressure sensitivity to vibrational sensitivity increases as the mass of the detectors increases. It is also greater for flat elements than for cylindrical elements.

Special detectors in which the principle of vibrocompensation is used: each detector includes two elements in which emf of one sign occurs during universal compression and with different signs during vibrations, have been developed to reduce sensitivity to vibrations. Appropriate joining of these elements leads to attenuation of the vibrational emf. A schematic diagram of the PDS-21 detector, the sensing elements in which are two identical cylinders separated by a rigid collar, is shown in Figure 12. Due to the effect of universal pressure P (see Figure 12, a), both cylinders are compressed and identical charges occur on the external plates. During the effect of acceleration in the direction shown by the arrow, a compression zone occurs in front of the first cylinder while a negative pressure zone occurs behind the second cylinder, which leads to the appearance of charges with opposite signs on the outer edges.

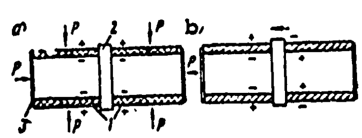

Figure 12. Schematic Diagram of PDS-21 Vibration-Resistant Detector. The signal polarity due to the effect of universal pressure (a) and of horizontal acceleration (b) is: 1 -- cylindrical piezoelements; 2 -- separating collar; 3 -- side mufflers

Because of vibrocompensation, the ratio of pressure sensitivity to vibrational sensitivity can be improved by a factor of 10-100.

Data on the most widely used domestic and foreign piezodetectors operating on the basis of TsTS materials are presented in Table 7.

It should be noted that deviations of the parameters of serial domestic detectors from mean parameters may reach ±5-7 percent in pressure sensitivity, ±10 percent in capacitance and ±100 percent in vibrational sensitivity, which is explained by the variation of properties of ceramics and the difficulty of selection and installation of identical pairs of elements.

It is of interest to analyze the level of the natural noise of a detector occurring in it due to temperature fluctuations for analysis of individual components of noise in the receiving channel. Analysis of the expressions presented in [79] shows that the noise emf of a detector $E_{sh.p}$ for the frequency range of $(f_2 - f_1) \leq 4$ kHz can be represented in the form

$$E_{ш.п} = [4k\, T_a A_r (\ln f_2 - \ln f_1)]^{1/2},$$

where k is a Boltzmann constant equal to $1.38 \cdot 10^{-23}$ erg/deg; T_a is absolute temperature; A_r is the parameter of a cylindrical detector with radius r, length l and wall thickness b:

$$A_r = (0.2 \div 1)\, E\, b \operatorname{tg} \delta / r^3 l,$$

where δ is the angle of losses.

Thus, the natural noise level of the detector decreases if a constant band is maintained with an increase of frequency. Noise reaches a minimum and then again increases at frequencies above 4 kHz. For a cylinder of TsTS with radius 1, length 5 and thickness of 0.2 cm, the value of $E_{sh.p}$ in the frequency band from 100 to 1,000 Hz is approximately 0.05-0.07 μV at T = = 20°C.

Having completed consideration of the natural properties of detectors with this, let us turn to the problem of signal transmission from them through the cable to the preamplifier. The equivalent schematic diagram of this system is shown in Figure 13. Here the detector is replaced by series connection of the emf generator E and capacitance C_p (the validity of this substitution in the frequency range much below resonance has been justified in many investigations -- see, for example, [70, 79]). The cable is represented by equivalent capacitance C_k and the input impedance of the preamplifier is represented by active resistance R_u. The length of the cable during seismoacoustic operations usually comprises 20-100 m (rarely greater), the linear capacitance is 50-100 pF/m, resistance is 0.03-0.1 ohms/m and inductance is 50-100 μH/m, i.e., C_k = 5,000-10,000 pF at the greatest length, which is quite comparable to the capacitance of a single detector (see Table 7),

Table 7. Characteristics of Piezodetectors [20, 67]

Емкость, пФ (1)	(2) Марка приемника	(3) Чувствительный элемент	(4) Чувствительность, мкВ/Па	(5) Длина, мм	(6) Диаметр, мм	(7) Масса, г	Вибрационная чувствительность, мкВс²/см (8)
		Отечественные (9)					
13000	ПКС-4	Цилиндр (10)	75	57	26	40	11
15000	ПКС-6	То же (10)	45	58	30	45	—
12500	ПДС-21	Два цилиндра (11)	100	72	30	49	1,3
16000	ПДС-7*	Два диска (12)	300	53	12×20		0,8
		Зарубежные (13)					
—	MP-8*	Две пластины (14)	400	98	17	24	—
6700	MP-12*	Пластина (15)	140	53	7	6	—
—	MP-14*	Две пластины (14)	600	53	10	12	—
30000	MP-16*	Четыре диска (16)	300	76	28×11	42	1,0
4700	P-25*	Две пластины (14)	145	95	10	16	—
13500	A-1	Цилиндр (10)	75	—	—	—	—
12000	H-201*	Два диска (12)	320	27	20	14	0,5
12000	H-301*	То же (12)	60	64	44	58	0,2

*Detectors with elements subject to bending deformation.

KEY:

1. Capacitance, pF
2. Mark of detector
3. Sensing element
4. Sensitivity, V/Pa
5. Length, mm
6. Diameter, mm
7. Mass, g
8. Vibrational sensitivity, Vs^2/cm
9. Domestic
10. Cylinder
11. Two cylinders
12. Two disks
13. Foreign
14. Two plates
15. Plate
16. Four disks

resistance is equal to 0.3-10 ohms and inductance is 5-10 mH. The inductive reactance of the cable is significantly less than its effective resistance, which in turn is much less than R_u, at frequencies of received signals up to 2,000 Hz. These analyses also lead to the equivalent circuit of Figure 12. Let us limit ourselves to the case of a short cable for which $C_p \gg C_k$; the modulus of input frequency characteristic, i.e., the ratio of the modulus of voltage $|U_R|$ at input impedance R_u to emf E occurring on the plates of the detector may then be written in the form

$$U_R/E = [1 + 1/(C_n R_y \omega)^2]^{-1/2},$$

while the phase shift between U_R and E is determined from the expression

$$\operatorname{tg} \varphi = 1/\omega R C_n.$$

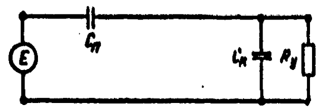

Figure 13. Equivalent Circuitry of Piezochannel

The input frequency characteristic of the piezochannel is nothing more than the characteristic of the RC filter of upper frequencies which provides transmission of frequencies above the boundary frequency f_{ng} (at level of 0.707), determined from the relation

$$f_{\text{нг}} = 1/2\pi R_{\text{у}} C_{\text{п}}.$$

At the given values of capacitance C_p and f_{ng}, this condition requires that the input impedance of the amplifier be no less than $(2\pi f_{ng} C_p)^{-1}$. For example, when using a single PKS-4 detector (C_p = 12,000 pF) and f_{ng} = 200 Hz, it is necessary that $R_u \gtrsim 70$ kohms. Such significant values of input impedances are undesirable when receiving weak signals (at the level of the first tens of microvolts) for the following reasons: high input impedances lead to high natural noises of the input stages; they require increased cable insulating resistors; spurious inductions may easily occur on them and so on. Therefore, except for special cases in which small dimensions of the receiving device are required, parallel connection of several identical detectors in a single receiving device is usually employed in practice. In this case the total capacitance C_p for a group of n_k detectors is increased n_k-fold, which permits a reduction of input impedance R_u by the same factor.

If the input impedance R_u is selected greater than required by the given condition, the piezochannel may be overloaded by low-frequency signals with components less than f_{ng} and the useful signals may fall into the nonlinear region of the input characteristic of the amplifier. For these cases some authors [79] recommend that additional low-frequency filters be placed in front of the amplifier.

The input signal level can be increased by using series-parallel connection of detectors, which permits an increase of the value of E_{pr} and C_0 [21].

If the length of the cable is significant, the shunting effect of its natural capacitance is excluded by placing the preamplifier in the immediate vicinity of the detectors.

Various emitter repeater circuits (based on ordinary and field transistors, microcircuits and so on) which have low input impedances while providing high values of R_u are most frequently used as preamplifiers. The latter makes it possible to eliminate the noise occurring in the cable. The fact is that the natural capacitance of the cable can be varied due to mechanical effects and the effect of external electric fields; this leads to the appearance of noise-induced emf on its conductors. Three-wire lines [79], the outer wires of which are connected to a group of detectors and the central wire of which performs the role of ground, are frequently led from the receiving device to the amplifier for this purpose. This line is connected to the input of the differential amplifier at whose output the signal from the detector is amplified, while inductions for each pair of lines (potential and grounding wire) are added in counterphase, i.e., the inductions are sharply attenuated if the conditions of symmetry of the differential amplifier input are observed.

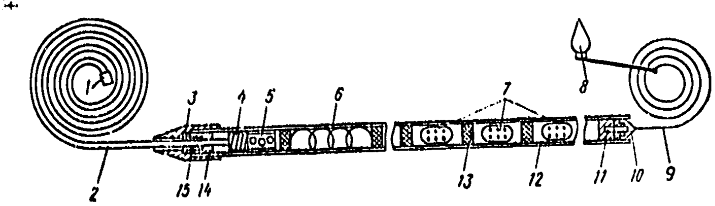

Figure 14. Longitudinal Section of the Receiving Device of a Piezoarray: 1 -- connector; 2 -- cable; 3 -- fairing; 4 -- storage batteries; 5 -- preamplifier; 6 -- spring shock absorber; 7 -- piezodetectors; 8 -- buoy; 9 -- stabilizer line; 10 -- end cap; 11 -- valve; 12 -- hose; 13 -- porolon plugs; 14 -- plug; 15 -- connection

The form of the receiving device, called a piezoarray or simply "array" is shown in the most complex version in Figure 14. A group of detectors connected in parallel and arranged at specific distances from each other is placed in a protective oil-filled hose. Hoses 45-55 mm in diameter of transparent polyvinyl chloride are most frequently used. Because of the transparency of the hose, one can visually monitor the safety of the detectors and the integrity of the connections. Hoses of polyvinyl chloride pipe of smaller diameter or rubber (Durite) hoses are sometimes used. The detectors occupy only the central part of the array and part of the free hose is left in front and back. Therefore, the detectors remain in the quietest part of the array at a distance from the disturbance zones caused by the front and rear part of the receiving device during towing in water.

A valve is located in the rear end cap of the array to supply solar oil under pressure. The excess pressure inside the hose is usually low (not more than 0.02-0.1 MPa). Other grades of oils with high insulating resistance may be used instead of solar oil: transformer, glycerine and so on. When oil is supplied to the array, measures are taken to prevent air and water entering it. The following procedure is frequently employed for this purpose under marine conditions. A weight is attached to the front end of the array and almost all of it is lowered into the water; oil is then poured into it through the open rear end and is helf for a long time (up to 10 hours) so that air bubbles leave, the rear end cap is then inserted with force and air residues are bled through the valve.

The front end cap has a connection for the cable lead. The preamplifier is located in the front part of the array. It is supplied from cells or storage batteries located in the array or is supplied by cable from the ship. Wires for external recharging of the storage batteries are frequently provided in the cable.

During the past few years receiving devices have been supplied with special shock-absorbing sections, which are a hose reinforced on the inside by a spring. Shock absorption contributes to attenuation of vibrational noise. Oil-impregnated porolon plugs are sometimes placed between each detector for the same purpose.

The front end cap of the detector is covered by a fairing which reduces drag during towing. A halyard with small buoy is frequently attached to the end of the array during operations with long cables, which makes it possible to follow the position of the array with respect to the ship and to find it if the cable breaks. In the absence of a buoy, if the array is short in length, the halyard or several halyards serve as stabilizers to reduce vibrations of the array during towing.

During seismoacoustic operations, the array is towed directly by the cable; therefore, it should not only have good insulating properties and elasticity, but should also tolerate appreciable tensile forces -- on the order of 0.3-0.6 kN.

Good quality of the profiling materials is also achieved at relatively low towing speeds (up to 5-6 knots) by using the simplest receiving devices consisting of 10-20 detectors of type PSK-4 or others arranged at a distance of 5-15 cm from each other. The detectors are placed in the hose closed on both ends by rubber plugs, which are wound on the outside by several turns of soft copper wire. A coaxial cable of type RK-50-41-21 is admitted through the front plug. The total length of the hose reaches 1.5-2.5 m.

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GEOPHYSICS, ASTRONOMY AND SPACE

COOPERATION IN SPACE RESEARCH

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 11, Nov 78 pp 80-87

[Article by N. S. Novikov, Deputy Chairman of the "Intercosmos" Council USSR Academy of Sciences]

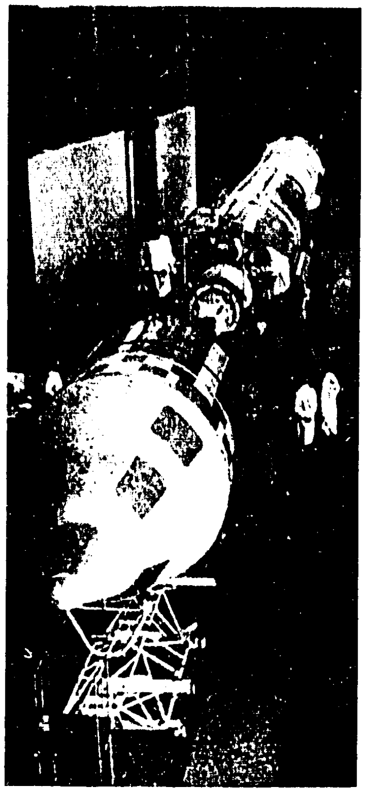
[Text] The Soviet Union cooperates with many countries in the study and mastery of space. In 1967 nine countries in the socialist camp -- Bulgaria, Hungary, East Germany, Cuba, Mongolia, Poland, Romania, the USSR and Czechoslovakia adopted a program of joint work which was later given the name "Intercosmos." National coordinating committees were established in these countries (in the Soviet Union, the "Intercosmos" Council USSR Academy of Sciences), made up of outstanding scientists and specialists.

Within the framework of the "Intercosmos" program there are five permanent mixed working groups: on investigation of the physical properties of space (space physics), on study of natural resources, on space communications, on space meteorology, on space biology and medicine. The principal task of the groups is ensuring the implementation and further development of the cooperation program. The groups are examining and solving problems relating to the feasibility of carrying out different kinds of scientific research studies and plans are laid for their realization.

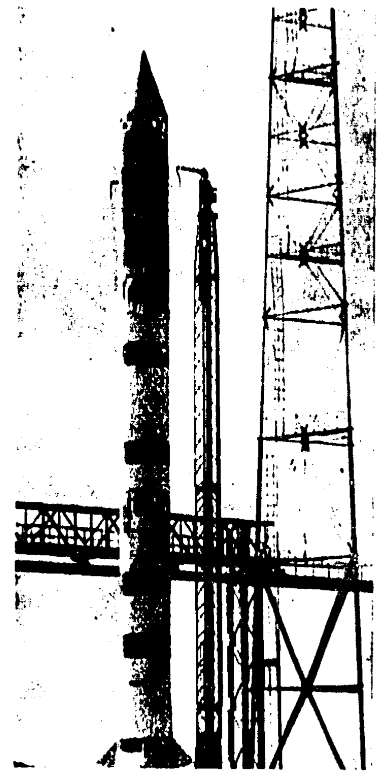
In implementing the "Intercosmos" program use was initially made of Soviet standardized artificial earth satellites, and later automatic universal orbital stations (AUOS -- avtomaticheskiye universal'nyye orbital'nyye stantsii). These carried three or four times more instruments than the preceding "Intercosmos" satellites. Up to 1 January 1978 a total of 17 satellites of the "Intercosmos" series and 6 "Vertikal'" geophysical rockets had been launched under the "Intercosmos" program.

The Soviet Union freely supplies its space and rocket technology to the socialist countries. The "Intercosmos" program facilitates the integration of space research and thereby the creation of new national cadres, the development of national science and modern industrial production in the participating countries. [For information on cooperation of the socialist countries under the "Intercosmos" program see: B. N. Petrov, "The

'Intercosmos' Program. Cooperation of the Socialist Countries," VESTNIK AN SSSR, No 6, 1977.]



Docking of the "Sneg-3" satellite (France) with carrier-rocket (USSR) in assembly-test building



Soviet carrier-rocket which launched the Indian "Ariabatha" satellite into space (1975)

The USSR is also developing cooperation in the study of space with the capitalist countries. France was the first capitalist country with which the Soviet Union signed an intergovernmental agreement on cooperation in space exploration (in 1966). The implementation of this agreement on the French side was assigned to the French National Space Research Center. Virtually all the work is carried out in four mixed working groups: on space physics, on space meteorology, on space communications, on space biology and medicine. Sessions of the working groups are held annually, alternately in the USSR and France. At these sessions specialists summarize results, plan new joint investigations and set the times and methods for carrying them out.

France is carrying out a major national space program. This country has modern space centers and a well-developed aerospace industry, a rocket launch site at Courou (French Guiana) and a network of satellite tracking stations. Its scientists and specialists have much experience in the study of space. All this has a favorable and productive influence on the development of bilateral cooperation.

Since the time of signing of the agreement there have been 28 joint Soviet-French experiments. French scientific instruments have been carried aboard the Soviet automatic interplanetary stations "Luna-17," "Luna-21," "Mars-5," "Mars-6," "Mars-7," "Venera-9," "Venera-10," and aboard the "Prognoz," "Oreol" and "Kosmos" satellites. Using French laser reflectors carried on board the Soviet lunokhods, it was possible to make a highly accurate determination (about 40 cm) of the distance from the earth to the moon.

Academician B. N. Petrov and Professor S. Davan (India) shake hands after signing the agreement on cooperation in work on the Indian satellite "Ariabatha" (Bangalore, 1973).

Soviet carrier-rockets were used in the launching of two MAS French technological satellites and the scientific satellite "Sneg-3" (gamma astronomy experiment).

In 1975 the extremely complex "Araks" experiment was carried out. Its objective was a refinement of the model of the earth's magnetosphere, the nature of behavior of the charged particles in it and the auroral mechanism. During this experiment a study was made of the phenomena causing auroras and the dynamics of charged particles in the earth's magnetic field. Two French "Eridan" rockets were launched on Kerguelen Island. They carried Soviet electron accelerators and also a complex of Soviet and French scientific instrumentation. Ground observations were carried out simultaneously on Kerguelen Island and at a conjugate magnetic region — in Arkhangel'skaya Oblast. Very valuable scientific results were obtained and these are being carefully analyzed by the scientists of the Soviet Union and France.

Within the agreed-upon program, the specialists of the USSR and France are preparing new experiments for investigating processes in the magnetosphere and ionosphere, the solar wind and the interplanetary medium, etc.

In accordance with the plans for research in the field of space biology and medicine, with the participation of France there was implementation of international complex biological experiments with the specialized biosatellites "Cosmos-782" and "Cosmos-936." In these experiments a study was made of the influence of spaceflight factors on living organisms. Scientists of both countries have carried out processing and analysis of the collected materials.

In February 1978 the "Salyut-6" orbital station was used in successfully carrying out the Soviet-French experiment "Tsitos" for study of the effect of spaceflight factors on the kinetics of cell division of microorganisms.

Joint work is successfully proceeding in the field of space meteorology. On Kerguelen Island there is regular rocket sounding of the upper atmosphere using Soviet M-100B meteorological rockets for obtaining data on temperature, wind and the concentration of atomic oxygen. Using numerical methods, Soviet and French specialists have obtained new data on mesoscale convective currents for different states of the air flow and thermal stratification of the atmosphere. Computations have been made of convective movements in a cyclone. The methods and instrumentation for rocket sounding are being systematically improved.

In 1977, in the region of the Kourou polygon (French Guiana), specialists carried out a second series of comparisons of Soviet and French meteorological sensors used for rocket sounding of the upper layers of the atmosphere. Launchings of Soviet rockets were carried out from the scientific research vessel "Akademik Korolev"; French rockets were launched from the Kourou polygon. There were 11 series of paired rocket launchings.

In 1977, on Kheys Island, the Soviet Union carried out 14 launchings of MR-12 rockets with French and Soviet instrumentation for measurement of the polar atmosphere by the method of artificial luminescent clouds at altitudes of 130-170 km. The purpose of these launchings was a study of the polar ionosphere under disturbed and quiet conditions. A French laser station has been operating on Kheys Island since 1975. It is employed for probing the upper atmosphere in the polar regions.

In the field of space communications, in 1977 specialists tested the digital telephonic communication line of the Space Research Institute USSR Academy of Sciences (Moscow) - NCSR (Toulouse). An agreement was reached that direct telephonic communication would be established between the Space Research Institute and the NCSR in 1978.

Cooperation between the Soviet Union and the United States of America in the exploration of space in actuality began to develop from the very beginning of the space era. The first bilateral agreement between the USSR Academy of Sciences and NASA in the United States was concluded in 1962. Joint experiments were carried out for establishing communications through space. A program was implemented for compiling a map of the earth's magnetic field. An around-the-clock exchange of information on the state of the atmosphere on our planet was arranged. A fundamental joint study entitled OSNOVY KOSMICHESKOY BIOLOGII I MEDITSINY (Principles of Space Biology and Medicine) was published.

During 1970-1971 there were meetings and discussions between the USSR Academy of Sciences and NASA, as a result of which a governmental agreement was signed in 1972 between the USSR and the United States on cooperation in the investigation and use of space for peaceful purposes. The agreement provided for the development of coordination in a number of fields of space research, joint implementation of experiments, and also exchange of scientific information on space. In this agreement a special place was devoted to studies on creation of joint means for the rendezvous and docking of Soviet and American manned spaceships and stations, including work on preparing the first joint experimental flight of the "Soyuz" and "Apollo" ships. [See K. D. Bushuyev, "First International Space Experiment," VESTNIK AN SSSR, No 4, 1976.]

Joint working groups were established for implementing the cooperation program: for studying circumterrestrial space, the moon and planets, for study of the environment, on space meteorology, on space biology and medicine.

During the time of cooperation much work was done on mapping the moon and investigating lunar ground. Scientists exchanged samples of lunar ground, sent one another catalogues of maps and photographs of the moon, and informed one another about the results of investigations and agreed to continue such work in the future.

A series of coordinated observations of the environment was carried out with the use of satellite, aircraft and surface apparatus. In accordance with the coordinated plans specialists in the USSR and the United States are continuing to study soils, vegetation, agricultural fields and hydrological characteristics in analogue sectors, but also investigations of the world ocean using space vehicles and special ships.

During September 1977 a Soviet-American experiment was carried out (within the framework of an international program) for the synchronous measurement of temperature of the Atlantic Ocean. Specialists are regularly exchanging the results of investigations carried out during 1976-1977 for study of microwave equipment, hydrology and oceanology, study of soils and vegetation.

Cooperation is being successfully developed in the field of space meteorology: the exchange of maps prepared on the basis of data from rocket sounding stations in the United States and the USSR in the altitude range 35-60 km, and also routine telegrams and summaries on rocket launchings. In August 1977, at Wallops Island (United States), there were comparisons of Soviet and American meteorological sensors used in rocket sounding of the upper layers of the atmosphere. During synchronous launchings of 22 pairs of Soviet M-100B meteorological rockets and American "Super-Loci-Datasonde" rockets measurements were made of wind velocity and temperature at greater altitudes. Investigations in the field of satellite meteorology were directed to improvement of methods for temperature sounding of the atmosphere.

In accordance with the plan for work in the field of space biology and medicine joint work is being carried out for study of the influence of spaceflight factors and especially weightlessness on the human and animal body. The efforts of scientists in both countries are directed to solution of a fundamental problem -- the possibilities of man's prolonged presence in space. The information collected on the state and behavior of the human body in space is being carefully processed and analyzed.

In November 1977 a symposium was held for discussing the problems involved in laboratory modeling of weightlessness conditions on the earth. The reports of Soviet and American scientists gave an analysis of the work done in each country and laid out the program for further investigations. Then the NASA Wallops Flight Center was the site of a session of a joint working group for examining the results of biomedical experiments aboard the Soviet biosatellite "Cosmos-936," aboard the "Soyuz-21" and "Soyuz-24" spaceships, and also on the "Salyut-5" orbital station. American scientists reported on the results of work on the ground simulation of flight of the "Spacelab" orbital station, carried out at the Johnson Space Center in 1977. Great attention was devoted to the problems of predicting man's state under weightlessness conditions and the possibilities of presence in space.

In May 1972 an agreement was signed at Moscow between the USSR Academy of Sciences and the Indian Space Research Organization of the government of India on the launching of an Indian satellite by means of a Soviet carrier-rocket from the territory of the USSR. At the request of India, the Soviet Union agreed to render India technical assistance in the designing of a satellite, and also to construct and supply gratis a number of systems, including a system for stabilizing the satellite, solar cells, a power supply system, and components of the telemetric system. In addition, on the proposal of the Indian Space Research Organization provision was made for creating near Moscow a ground station for the reception of telemetric information from the satellite and for the transmission of commands.

As is well known, the Indian satellite "Ariabatha" was developed and constructed in a short time -- in two years. On the Soviet side, a large group of scientists and specialists participated in this work.

The "Ariabatha" satellite (weighing 360 kg) is the largest and most complex of all the pioneering satellites. On 19 April 1975 the satellite was put into the computed orbit. It implemented the program and continues to fly. Indian scientists have obtained valuable scientific and technical information in the field of space physics and presented interesting reports at the Eighteenth COSPAR Session at Varna (Bulgaria) and at the Seventh International Seminar on Space Physics at Leningrad.

At the present time, in the outskirts of Bangalore, at the base where the "Ariabatha" satellite was launched, a center of the Indian Space Research Organization was organized for creating satellites; it was headed by Profesr U. R. Rao. There specialists are developing a whole series of satellites for scientific and practical purposes, including a satellite for observing the earth's surface (CEO), on the basis of the second "Ariabatha" flight model. This satellite, like the first, is being created with the participation of Soviet scientists and specialists.

In April 1975 a new agreement was signed between the USSR Academy of Sciences and the Indian Space Research Organization. This was an agreement on the launching of a second Indian earth satellite (weight 400 kg) by a Soviet carrier-rocket from the territory of the Soviet Union. It will carry scientific instrumentation for investigating the earth's surface. Microwave radiometers and television cameras with vidicons will make it possible to register the cloud cover, measure temperature of the ocean surface, obtain information on the snow cover in the Himalayas, the rate of thawing of the snow, and also other data important for meteorologists and hydrologists. This satellite will undoubtedly be of great importance in solving problems in the national economy of India.

The rendering of scientific and technical assistance to India in the creation and launching of satellites, naturally, is not the only form of our cooperation in the investigation and use of space. Over the course of many years Soviet and Indian meteorological rockets have been launched from the equatorial polygon at Thumba. During 1977 74 Soviet M-100B rockets were launched for investigating the structure and circulation of the upper atmosphere in the low latitudes and also for studying the relationship between stratomesospheric phenomena and solar activity. Instrumentation of both countries was carried aboard the rockets.

Both sides regularly exchange information relating to weather forecasting.

During October-November 1977 joint experiments in the field of gamma astronomy were carried out in India. For this purpose at the Hyderabad polygon there was a series of launchings of high-level balloons. These investigations, overlapping the fields of astrophysics, the physics of cosmic rays and elementary particles, are of great importance in the study of problems relating to the origin of cosmic rays, the presence of antimatter in the universe, etc. The high-altitude balloons, with all their auxiliary equipment, were supplied by the Indian side. Soviet scientists constructed complex scientific instrumentation -- gamma telescopes making it possible to carry out observations with a great accuracy. The information obtained is being processed at the Physics Institute imeni P. N. Lebedev USSR Academy of Sciences and at the Tata Physical Institute of Fundamental Research at Bombay. Experiments of this type will be continued during 1978-1979.

Soviet-Swedish cooperation in the space field is being carried out on the basis of the Intergovernmental Agreement on Economic and Scientific-Technical Cooperation Between the USSR and Sweden (January 1970) and the cooperation agreement between the Royal Swedish Academy of Sciences and the USSR Academy of Sciences. The coordination of joint work is the responsibility of the "Intercosmos" Council USSR Academy of Sciences and the Swedish Space Activity Administration.

In 1976 the Physics Institute imeni P. N. Lebedev USSR Academy of Sciences, the Crimean Astrophysical Observatory and Lund University used the "Intercosmos-10" satellite for carrying out an experiment for study of solar UV radiation. Swedish specialists, with the participation of Soviet scientists, developed and fabricated a unique spectrometer-polarimeter and participated in studies at the cosmodrome for its installation aboard the satellite. An analysis of the results of these investigations indicated that the collected data are of great scientific interest.

Preparations are being made for a joint Soviet-Swedish experiment PROMIKS for investigating the total composition of hot plasma in the earth's magnetosphere using a mass spectrometer fabricated by Swedish specialists with the participation of Soviet scientists. In January 1978 Soviet specialists participated in tests and acceptance of a working sample of the spectrometer at the Kiruna Geophysical Institute. In July Swedish specialists carried out tests of flight models of the instrument at the Space Research Institute USSR Academy of Sciences.

This experiment will be carried out using a high-apogee "Prognoz" automatic station, designed for studying solar activity and its influence on the interplanetary medium and the earth's magnetosphere. The planned investigations are of great importance for the scientific prediction of radiation conditions in space. In the future there may be a complex experiment for the study of the physics of magnetospheric processes which is more complex and promising in scientific respects. There is now discussion of other joint experiments for the exploration of space, including space technology.

In 1976 the Soviet Union proposed to all countries participating in the "Intercosmos" program that international flights be carried out aboard Soviet spaceships and orbital stations with participation of representatives of these countries. The proposal was adopted, screening of cosmonaut candidates was initiated, and the first such group proceeded to training in this same year at the Cosmonaut Training Center imeni Yu. A. Gagarin.

The first flight with an international crew took place in March 1978 aboard the "Soyuz-28" spaceship, which docked with the "Salyut-6" orbital station. The ship commander was USSR Flier-Cosmonaut Aleksey Gubarev, whereas the cosmonaut-researcher was a citizen of the CzSSR, Vladimir Remek. Scientific experiments were carried out aboard the "Salyut-6," after which the "Soyuz-28" crew completed its expedition and returned to the earth.

In June 1978 the "Soyuz-30" spaceship was launched; it carried a second international crew: the ship commander USSR Flier-Cosmonaut Petr Klimuk and cosmonaut-researcher Miroslaw Hermaszewski, a citizen of the Polish People's Republic. The ship docked with the "Salyut-6"-"Soyuz-29" orbital complex. Once again the manned "Salyut-6"-"Soyuz" scientific research complex was created in a circumterrestrial orbit. The cosmonauts carried out a major program of scientific research and experiments in the fields of space technology, biomedical problems and investigations of the earth's surface in the interests of different branches of the national economy.

The "Soyuz-31" spaceship was launched in August. It carried a third international crew, consisting of ship commander USSR Flier-Cosmonaut Valeriy Bykovskiy and cosmonaut-researcher Sigmund Jaehn, a citizen of the German Democratic Republic. The ship docked successfully with the "Salyut-6"-"Soyuz-29" orbital complex. The cosmonauts carried out biomedical and technological experiments, investigations of physical processes and phenomena in the earth's atmosphere, visual observations and photographing of the earth's surface and the waters of the world ocean for the purpose of study of natural resources.

The first flights of international crews, successfully carried out, are opening up a qualitatively new stage in scientific investigations of space. Cosmonauts of other countries participating in the "Intercosmos" program are now undergoing training at Star City. In accordance with the plan, all crews now in training will carry out space flights aboard Soviet ships in the next few years.

Cosmonautics has gone a long way since the launching of the world's first artificial earth satellite on 4 October 1957. Today cosmonautics is faced with new, more complex problems and scientists throughout the world must still more actively join their efforts for solution of these problems for the welfare of all mankind.

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GEOPHYSICS, ASTRONOMY AND SPACE

A REFLECTING X-RAY TELESCOPE FOR AN ORBITAL ASTROPHYSICAL STATION

Mosocw RADIOTELESKOPY, SUBMILLIMETROVSKIYE I RENTGENOVSKIYE TELESCOPY in Russian Vol 77, 1974 pp 3-13

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[Text] Introduction

The classical tool for studying cosmic X-ray radiation sources is a photon counter, equipped with a mechanical collimator system to detect radiation from individual sectors of the celestial sphere. Such "collimating telescopes" were used right at the inception of X-ray atronomy in 1962, and in particular, in the especially fruitful experiment with the "Uhuru" satellite [1]. However, for a number of years now, considerable attention has been devoted to "grazing incidence" reflecting X-ray telescopes. Such telescopes are particularly promising for research in the soft X-ray region of the spectrum, $\lambda > 10$ Å ($E < 1$ Kev). At shorter wavelengths, the grazing angle of the beam should be extremely small ($< 1°$), and to obtain a significant effective area, reflectors are required having a focus of several meters. Studies of soft X-ray radiation sources have already been carries out using reflecting telescopes installed in rockets [2 - 5].

The basic advantage of a reflecting telescope is the capability of concentrating the X-ray radiation from a large area onto a detector with small dimensions. This significantly reduces the contribution from the cosmic ray background. Moreover, the detector proves to shielded from the soft electronic component. Finally, an important advantage of a reflecting telescope is the fact that because of the small area of the entrance aperture of the counter, thinner films can be used, something which is especially important in the soft X-ray range, where films of even a few microns markedly absorb the radiation. There also arises the possibility of using other types of small area detectors, for example, channel multipliers and semiconductor detectors.

It stands to reason that the design of a reflecting telescope involves additional engineering difficulties. These difficulties increase substantially if the next step is taken, that of going on to the plotting of the X-ray image using a coordinate sensitive detector. However, we did not pose this problem in this case. The small field of view of the telescope with a paraboloidal reflector also makes additional demands on the precision of telescope guidance on an object.

The RT-4 reflecting X-ray telescope is described in this paper, which intended for studying the soft X-ray radiation of discrete sources using orbital astrophysical stations. Besides the telescope itself, the apparatus has independent control and astral orientation systems, which are not discussed here. A general description of the device is given in Section 1, while in Section 2 there is a detailed description of its individual assemblies.

1. The General Configuration of the Telescope

The reflecting X-ray telescope is designed for observations in the soft X-ray region of the spectrum at 40--60 Å. The telescope is designed for installation in orbital stations, which provide for an observation time of one source of 10 minutes and more.

A general view and the configuration of the telescope are shown in Figures 1 and 2. The X-ray radiation is focused by the parabolic reflector on the input aperture of the proportional photon counter. The stop at the reflector aperture does not allow direct rays which have not been reflected to fall on the counter, and also attenuates the soft electron flux component.

The spectral sensitivity range of the telescope is determined by the transparency of the counter window film (2 μm polypropylene)*. Moreover, the reflector effectively reflects radiation only at $\lambda > 15$ Å.

A rotating filter, which periodically shutters the X-ray radiation beam, serves to determine the count level from the penetrating cosmic background and ultraviolet radiation. The filter is made from quartz, which is transparent for ultraviolet radiation in a range of $\lambda > 1,700$ Å.

The thin organic film of the counter windows does provide for a complete hermetic seal, and for this reason, during an observation session, the counters are coupled by means of an electric pneumatic valve to a tank with a capacity of 3.6 liters, which contains a gas mixture. Between sessions, the counters are disconnected from the tank and a significant fraction of the gas flows

* The authors are grateful to V.A. Nazarov for his active participation in the development of the technology to obtain thin polypropylene films and to O.D. Lesnyye (the "Plastpolimer" Scientific Production Association, Leningrad) for the samples of the original, high homogeneity nonoriented film.

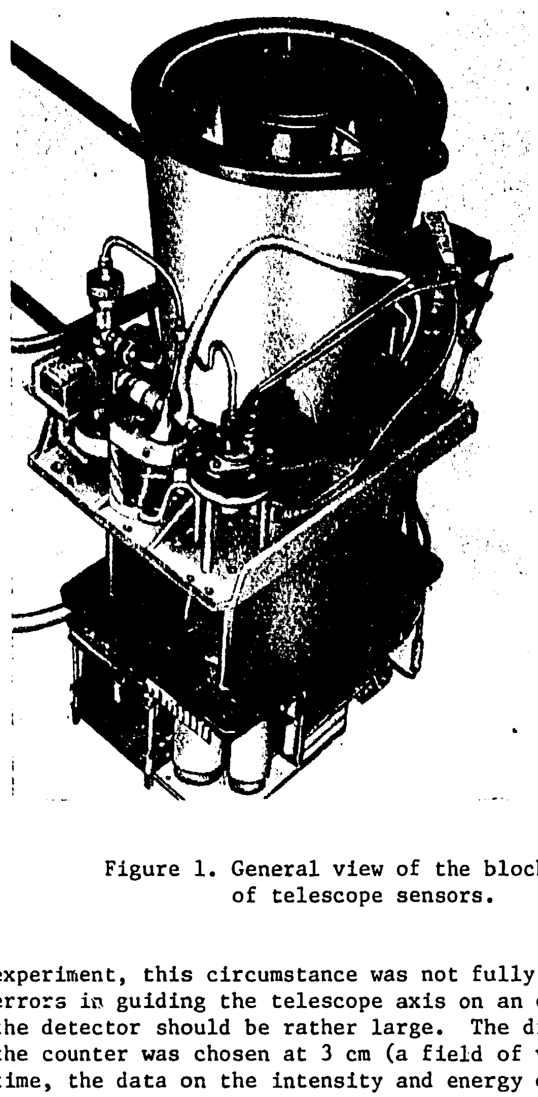

Figure 1. General view of the block of telescope sensors.

out from the volume of the counters (≈ 100 cm^3). A high voltage power supply regulator serves to assure constancy of the cell amplification factor factor during the gradual reduction of the gas pressure in the tank.

A description of the individual components of the telescope is given in the next section. Here we will deal only with the data which characterize telescope sensitivity (see Section 2).

The effective reflector area for $\lambda = 44$ Å, taking into account the reflection factor from the Ni coating, is $S_X = 100$ cm^2. The counter efficiency at this wavelength is $\eta_0 = 0.3$. Thus, the telescope efficiency is $\eta_0 S_X =$ $= 30$ cm^2/photon in a range of $\Delta E = 0.07$ Kev.

The minimum detectable flux depends on the count level for the cosmic ray background, C_N, the X-ray background C_X and on the observation time. The use of the reflector permits a reduction in the size of the detector, and consequently, in the quantity C_N. However, in our first experiment, this circumstance was not fully utilized: because of the possible errors in guiding the telescope axis on an object being studied, the size of the detector should be rather large. The diameter of the entrance window of the counter was chosen at 3 cm (a field of view of $\pm 1.8°$. At the present time, the data on the intensity and energy distribution of the cosmic ray background in the 0.1 -- 0.6 Kev range of interest to us is inadequate. Apparently, for a counter with a 3 cm window, one can hope to obtain a value of $C_N < 1$ pulse /sec (see Section 2, paragraph "b"). Assuming an observation time of 500 seconds, we obtain a value (at the 3σ level) of F_{min} (0.28—0.20 Kev) = $6 \cdot 10^{-2}$ photons/$cm^2 \cdot$ sec, something which agrees with a flux density of F_{min}(0.28 Kev) = 0.1 photons/cm^2 · sec · Kev. The anticipated count rate from the diffuse X-ray background in the galactic plane is equal to $C_d \approx 1$ pulse/sec.

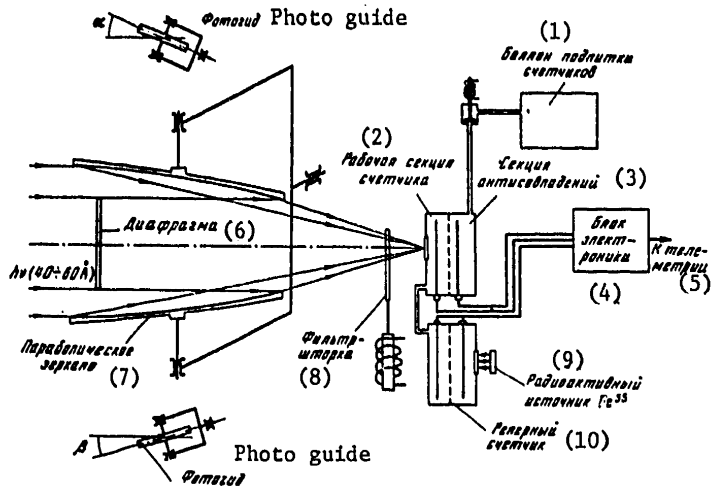

Figure 2. Configuration of the X-ray telescope

Key: 1. Make-up tank for the counters;
2. Working section of the counter;
3. Anticoincidence section;
4. Electronics module;
5. To telemetry;
6. Diaphragm stop;
7. Parabolic reflector;
8. Filter blind;
9. Fe^{55} radioactive source;
10. Reference counter.

2. The Main Components of the Telescope

a) The Reflector

The reflector of the telescope takes the form of a truncated paraboloid. The paraboloid does not meet the Abbe sine condition, i.e., produces a considerable coma for rays outside the axis and does not permit obtaining an image of an object. As is well known, coma can be eliminated by using double reflection, for example, a paraboloid and hyperboloid in combination. However, in our case, with a relatively large counter window size (3 cm), there was no need for this. Besides, the use of two surfaces markedly decreases the effective area.

The reflector has an opening area of 19.7 cm and the distance from the focal point to the entrance aperture is 62.4 cm. The shape of the reflecting surface is described by the equation

$$1.52z = x^2 + y^2, \qquad z = 18.6 -- 62.8$$

(dimensions in cm). The grazing angle for axial beams varies from 8.2 to 4.5°.

The experimental data of [6, 7] on the reflection factors for various materials show that the optimum coating for the spectral range $\lambda > 44$Å is nickle.

The effective area S_x which was calculated on a computer for different diameters with a fixed focal distance shows that when $\lambda = 44$ Å, the diameter chosen yields $S_x = 144$ cm^2 [8]. This is only 20% less than the area for the case of the optimal diameter. When $\lambda = 77$ Å, $S_x = 181$ cm^2. For comparison, we shall indicate that the total collecting area (for a reflection factor of unity) is $S_0 = 211$ cm^2.

The reflecting surface of the reflector was fabricated by means of taking replicas* from a polished, specified paraboloidal shape which was polished by a standard method. The replica was obtained by electrolytic deposition of an Ni layer ≈ 0.1 mm thick, on which copper was then built up to the requisite thickness (≈ 1.5 mm). Such reflectors are considerably easier than glass ones. It is not difficult to fabricate several copies from one matrix.

The reflection factor from the surface element of a replica was measured using an X-ray monochromator. The resulting curve obtained for the reflection factor as a function of the grazing angle at $\lambda = 44.4$ Å is shown in Figure 3, along with the reflection factor for optically polished samples [6]. The somewhat lower value of the reflection factor in our case is apparently explained by the insufficient purity of the polishing of the matrix.

Since the diameter of the entrance window of the counter is comparatively large, no severe requirements were placed on the quality of the shape of the surface generatrix of the reflector. The distribution of the intensity in the focal plane of the paraboloid for a parallel axial beam, measured in the visible region of the spectrum, is shown in Figure 4. The diameter of a scattering spot is 3 mm. Its stands to reason that a scattering spot in the X-ray region can be greater due to the increase in the requirements placed on the quality of surface polishing.

The field of view of the telescope was also studied in the visible range. The resulting curve for the flux assa function of the angle the main beam

* The technology for obtaining the replicas was worked out by E.V. Tver'yanovich (VNIIT, Moscow).

makes with the optical axis of the reflector is shown in Figure 5. The angle between a parallel beam and the optical axis of the telescope is plotted along the abscissa. As can be seen from the figure, the field of view is ± 1.8°. It should be noted that a scattering spot from a point object is asymmetrical, where the illumination maximum is displaced towards the axis. This leads to a marked increase in the field of view as compared to the field of view defined by the geometric center of the spot. The latter definition was used in the calculations of [8], which yield a field of view of ± 1.3° in our case. The calculation of the aberrations, which was performed on a computer, confirmed the experimental result given above [8].

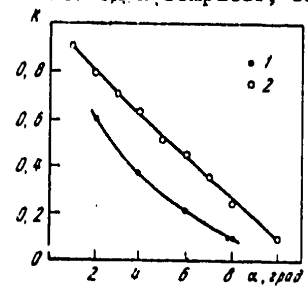

Figure 3. The reflection factor at λ = 44.4 Å.

Key: 1. Nickel replica;
2. Optically polished sample [6].

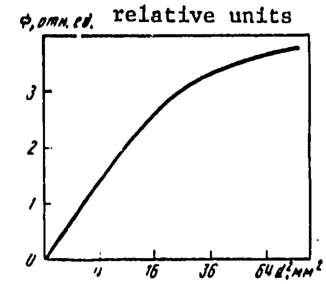

Figure 4. The light flux as a function of the square of the diameter of the detector entrance window.

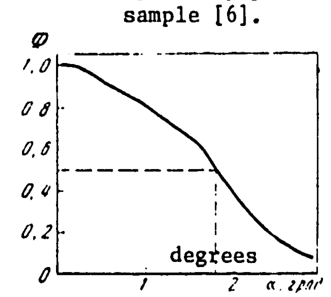

Figure 5. The light flux as a function of the beam angle with respect to the optical axis of the reflector.

b) The Photon Counter

A SRPP-36 proportional counter was used in the telescope. The counter has the shape of a short cylinder, split into two parallel sections, where the anode filaments are located along the diameter of each section (Figure 6).

The sections of the counter are separated by beryllium foil 0.1 mm thick. The upper section is used to record soft X-ray radiation. The lower section is connected in the instrument in an anticoincidence circuit configuration with the upper one and serves for reducing the count rate from the cosmic background.

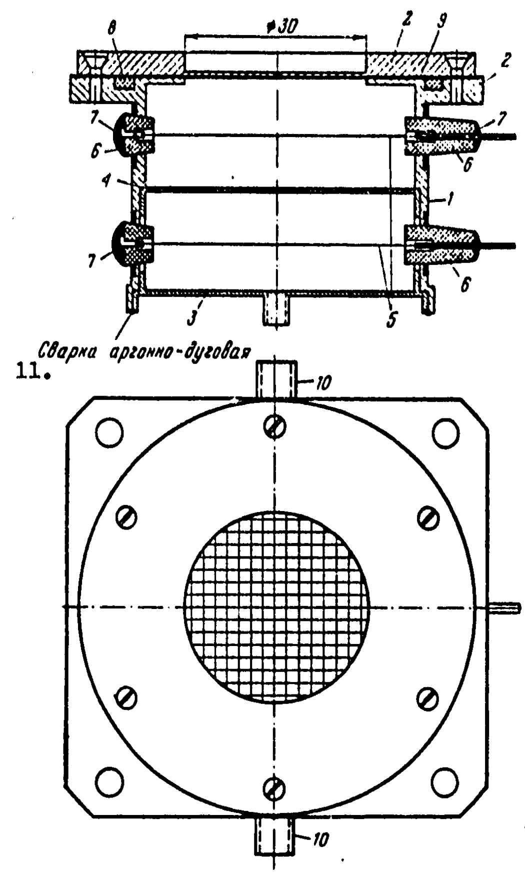

Figure 6. The SRPT-36 proportional X-ray counter.

Key:
1. Housing (AMPs alloy):
2. Window grating (U8 steel);
3. Base (AMTs alloy);
4. Diaphragm (beryllium, 0.1 mm);
5. Anode "filaments";
6. Ceramic insulators;
7. G ued connection;
8. Rubber seal;
9. Window (polypropylene, 2 μm);
10. Inlet and outlet connection;
11. Argon arc welding.

The upper section has the entrance window, which is covered by a polypropylene film 2 μm thick, supported from the outside by a steel grating. The diameter of the window is 3 cm. The counter is filled with a gaseous mixture of 90% Ar plus 10% CH_4 up to a pressure of 1--2 atm.

The gas leaks out through microleaks when the fine organic film is employed. An operational mode using individual sessions with intervals of 24 hours and more between them is planned for our telescope. During the time between sessions, the gas practically completely leaves the volume of the counter. For tnis reason, the counter is cut off between sessions from the tank with the gas mixture and is connected to it only during the time of the session. The gas filling system unit is shown in Figure 7. By means of carefully selecting film samples, success has been achieved in assuring a leakage of no more than 10^{-2} cm^3/min with a pressure gradientof 1 atm. In this case, gas loss during the time of a session amounts to only a small fraction of the counter volume.

The entrance window film isolates a spectral range of 0.28--0.20 Kev (44--60 Å). To reduce sensitivity to ultraviolet radiation, the interior surface of the counter is coated with a graphite layer, while a layer of carbon at 40 μg/cm^2 is deposited on the exterior surface of the entrance window film. A thin layer of aluminum is deposited on the interior surface to assure conductivity. The transparency of this film to radiation in the 1,800 Å region does not exceed 10^{-3}.

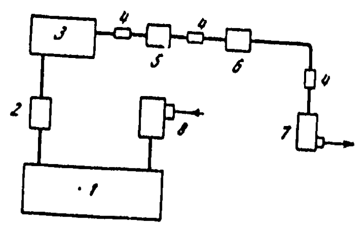

Figure 7. The gas filling system.

Key:
1. Tank with a quenching mixture of 90% Ar plus 10% CH_4;
2. Filter;
3. Pulsed electrically operated valve, which automatically opens when the power supply of the instrument is turned on;
4. Rubber coupling sleeves;
5. Working counter;
6. Reference counter;
7. Drain valve;
8. Filling valve.

The cell amplification factor amounts to about 10^4. The counter operates in a proportional mode with pulse recording in an energy range of 0.6--0.1 Kev.

The distribution of the amplitudes for the case of monochromatic irradiation with an Fe^{55} (2.09 Å) source is shown in Figure 8. The distribution half-width is 25%.

The proportionality of the mean amplitude of a pulse of photon energy was checked in a range of 0.36--6 Kev. The presence of proportionality permits the use of a Fe^{55} radiation source for debugging and testing the instrument, where it is possible to work with this source at normal atmospheric pressure, in contrast to the working spectral range of about 44 Å.

The design value of counter efficiency η_0 is defined by the transmittance τ_0 of the window ahead of the K absorption edge (E_0 = 0.28 Kev) and the effective energy range:

$$\Delta E = E_0[1-(1+1/\tau_0)^{-1/3}],$$

where τ_0 is the optical thickness of the film. It is assumed that $\tau(E) = \tau_0 (E_0/E)^3$. The quantity $\eta_0 = Ke^{-\tau_0}$, where K = 0.5--0.7 is the transparency of the grating. For a 2 μm polypropylene film or space + 40 μg/cm^2 C, the design values are: τ_0 = 0.7; η_0 = 0.30; and ΔE = 0.07 Kev.

The value of η_0 was measured by isolating a narrow range around 0.28 Kev from the spectrum of the X-ray tube using a filter of thick lavsan [synthetic fiber similar to dacron] film. A Lukirskiy counter with a known absolute sensitivity seved as the calibration standard [10]. The resulting value of η_0 was close to the design figure. Thus, the overall efficiency of the telescope is $S_x \eta_0 \Delta E \geq 2$ cm^2 · Kev.

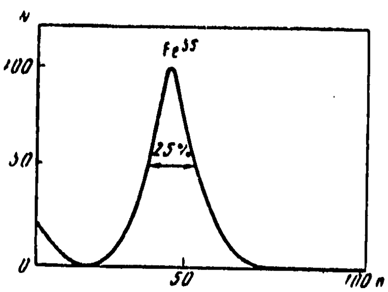

Figure 8. The amplitude distribution of the pulses for the case of irradiation with an Fe^{55} source.

Plotted on the abscissa: the numbers of the pulse analyzer channels (which are proportional to the pulse amplitude).

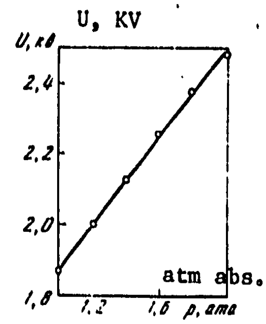

Figure 9. The working voltage of the telescope counter as a function of the gaseous mixture pressure.

Shown in Figure 9 is the working voltage of the telescope counter as a function of the gas pressure. The voltage is automatically regulated by means of a "reference" counter of similar design, which is constantly irradiated by a Fe^{55} source (see Section "c").

c) The Electrical Circuitry of the X-ray Telescope

The major components of the telescope circuitry are:

1) A circuit for measuring the pulse count rate;

2) A power supply voltage regulator for the proportional counter;

3) A control circuit for the filter drive and the blocking of the inputs of the working and monitor channels;

4) A regulated power supply;

5) A control circuit for the pulsed pneumoelectric valve;

6) A pneumoelectric valve and filter position indicator, gas pressure sensor and temperature sensor.

A block diagram of the telescope is shown in Figure 10.

The measurement circuitry contains the pulse amplifiers 18 and 25 for the working section of the counter and pulse amplifier 17 for the monitor section, pulse sampling assembly 24, count circuits 33 and 34, and the "adders" 32 and 35 - convertors for converting the state of the count elements analog form.

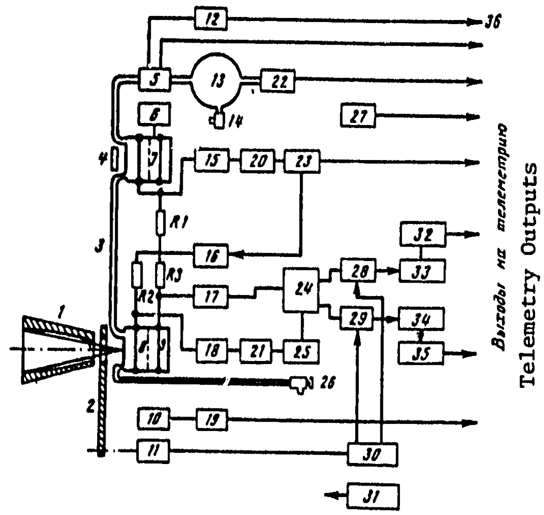

Figure 10. Block diagram of the telescope

Key:
1. Telescope reflector;
2. Rotating filter;
3. Gas line;
4. Radioactive source;
5. Pneumoelectric valve;
6. Bias supply source;
7. Reference counter;
8. X-ray section of the working counter;
9. Monitor section of the working counter;
10. Photoelectric sensor for the position of the filter;
11. Filter drive;
12. Pneumoelectric valve control circuit;
13. Tank with the gas mixture;
14. Filler valve;
15. Input stage of the reference counter amplifier;
16. Variable high voltage converter;
17. Input stage of the monitor section amplifier;
18. Input stage of the X-ray section amplifier;
19. Amplifier for the photoelectric sensor for the filter position;
20. Amplifier stage of the reference counter;
21. Amplifier stage of the X-ray section;
22. Pressure sensor;
23. High voltage regulator;
24. Anticoincidence and discrimination circuit;
25. Pulse driver;
26. Drain valve;
27. Temperature sensor;

28 ,29. Blocking switchers;

30. Control unit for the filter drive and blocking the inputs;
31. Regulated power supply converters;
32. Adder;

33 ,34. Count gate;

35. Adder;
36. Valve control commands.

If the amplitude of the pulses exceeds the reference voltage, then the voltage at the output of the high-voltage power supply converter of the counter is reduced. An RC filter with a time constant of ≈ 30 seconds is inserted in the power supply circuit for the counters.

Under laboratory conditions, the voltage regulator permits maintaining the amplitude of the counter pulses within limits of ± 10% when the gas mixture pressure varies from 2.6 to 0.9 atm and when the temperature of the mass of the block of sensors varies within limits of ±60° C. Interference from the recording by the reference channel of the background of primary cosmic rays reduces the upper limit of permissible pressures down to 1.6 atm.

The control circuit for the filter drive and blocking the inputs of the working and monitor channels, 30, generates the voltage necessary for powering the solenoid, by means of which the filter is moved, and also generates signals for blocking the inputs of the count gates (by means of diode switches 28 and 29) for the time needed to shift the filter from one position to another. Blocking the inputs prevents interference to the count gates during filter changeover.

The circuit consists of a generator of second pulses, count gates, which determine the open and closed position times of the filter, and an amplifier stage. The sequential exposure time without the filter is ≈40 sec, and with a quartz filter in front of the entrance window of the main counter, it is ≈ 10 sec.

Power supply regulator 31 contains an input voltage regulator, a push-pull converter and an output voltage regulator. The power supply is designed for working with an input voltage of 27 + 7 or - 4 volts and provides for the following output voltage to power the telescope circuits: 6.3 volts ± 5% and 1.2 volts ± 5% to power the count circuits; 12 volts ± 1% to power the amplifier stages; and 13.5 volts ±5% to power the high-voltage converter. Moreover, the power supply provides for galvanic decoupling of the primary power source from the electrical recording circuit.

The control circuit for pulsed pneumoelectric valve 12 is designed around a one-shot multivibrator, which actuates when the power is turned on. It feeds a pulsed voltage with an amplitude of 27 + 7 or - 4 volts for 0.1 sec to the winding of the electric valve (resistance of 30 ohms).

The filter position indicator consists of light sources - two miniature incandescent bulbs, silicon photodiodes and amplifier stages. The output signals of the unit yield information on the position of the filter.

The free contacts of the valve are used to indicate the position of the pneumoelectric valve.

A pulse current amplifier with a gain of $K = 5 \cdot 10^4$ is used to amplify the pulses of the proportional counter. The variation in the gain of the amplifiers with a change in the ambient temperature from -60 to +60° C does not exceed ±5%. The internal amplifier noise is $3 \cdot 10^{-15}$ k.

The pulse sampling assembly consists of an amplitude gate and an anticoincidence circuit. The pulse sampling provides for the recording by the count circuit of the working channel of the pulses from the working section of the counter, which correspond to the photons in spectral range of 0.1--0.6 Kev, and do not coincide in time with the pulses of the monitor section of the counter.

Amplitude gating of the pulses is accomplished by means of a circuit designed around tunnel diodes. The anticoincidence circuit is designed around slaved blocking oscillators.

Sensitivity changeover switch 21 is inserted in the amplifier channel of the working section of the counter, where this switch permits reducing the gain by 50 times. This switch is used in the laboratory alignment of the recording channel. In the low sensitivity mode, the pulses from the Fe^{55} source (E = 5.94 Kev) appear at the lower boundary of the recordable amplitudes of the working channel.

The count circuits for the working and monitor channels contain four binary flip-flops each and operate in a continuous mode. The state of the count elements is converted to analog form by means of summing the currents of each flip-flop, taking into account its weighting factor in the total information. A voltage proportional to the total current of the flip-flop is fed to the input of the telemetry system. This voltage changes in steps following the arrival of a sequential pulse to the input of the count circuit. With a fast interrogation telemetry system, this type of conversion makes it possible to register the arrival of each pulse from the counter.

The power supply voltage regulator for the proportional counter: during the time the equipment is in operation, the gas mixture in the tank is gradually expended, and the pressure falls off, something which necessitates a corresponding change in the power supply voltage to the counter. A regulator is used for this purpose, which includes a reference source 4, the isotope Fe^{55}, proportional counter 7, pulse amplifier 15, high-voltage regulator 23, high voltage converter 16 and bias voltage converter 6. The voltage controller operates on a tracking system principle, which maintains the constancy of the pulse amplitude of the counter irradiated by the reference source.

The primary and reference counters have a common gas feed from the tank, i.e., they operate at the same pressure. The reference counter is constantly irradiated by the radioactive source. The amplified pulses of the reference counter (a count rate of $\approx 10^3$ pulses/sec) are fed to the input of the high-voltage regulator, where their amplitude is compared to the reference voltage.

In conclusion, the authors consider it their pleasant duty to express their gratitude to V.I. Shurygin, V.A. Slemzin, V.I. Svirin, V.A. Drozdovskiy, A.I. Parshin and V.A. Nazarov for assisting in the fabrication of the instrument.

BIBLIOGRAPHY

1. R. Giacconi, E. Kellogg, P. Gorenstein, H. Gursky, H. Tananbaum. ASTROPHYS. LETTERS, 165, 27 (1971).

2. P. Gorenstein, B. Harris, H. Gursky, R. Giacconi, R. Novick, P. Vanden Bout. SCIENCE, 172, 369 (1971).

3. D.J. Yentis, R. Novick, P. Vanden Bout. ASTROPHYS. J., 177 part I, 365 (1972).

4. D.J. Yentis, J.R.P. Angel, D. Mitchell, R. Novick, P. Vanden Bout. New Techniques in Space Astronomy (IAU SYMPOS. 41), 1971, p. 145.

5. P. Gorenstein, A. De Caprio, R. Chase, B. Harris, REV. SCI. INSTR., 44, 539 (1973).

6. A.P. Lukirskiy, Ye.P. Savinov, O.A. Yershov, Yu.F. Shepelev, OPTIKA I SPEKTROSKOPIYA, 16, 310 (1964).

7. O.A. Yershov, I.A. Brytov, A.P. Lukirskiy, OPTIKA I SPEKTROSKOPIYA, 22, 127 (1967).

8. I.L. Beygman, L.A. Vaynshteyn, Yu.P. Voynov, V.P. Shevel'ko, TRUDY FIAN, [PROCEEDINGS OF THE INSTITUTE OF PHYSICS OF THE USSR ACADEMY OF SCIENCES], 77, 14 (1974).

9. R. Ciacconi, W.P. Reidy, G.S. Vaiana, L.P. Vanspeybroeck, T.F. Zehnpfennig, SPACE SCI. REVS., 9, 3 (1969).

10. A.P. Lukirskiy, I.A. Brytov, O.A. Yershov, IZV.AN SSSR [PROCEEDINGS OF THE USSR ACADEMY OF SCIENCES], PHYSICS SERIES, 27, 446, (1963).

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PHYSICS

INFLUENCE OF TURBULENT ATMOSPHERE ON WAVE BEAM FIELD FLUCTUATIONS

Moscow KVANTOVAYA ELEKTRONIKA in Russian Vol 5 No 11 1978 pp 2342-2347

[Article by G. Ya. Patrushev: "Wave Beam Field Fluctuations Upon Reflection in Turbulent Atmosphere"]

[Text] An approximation of the smooth perturbation method has been employed to derive second moment fluctuations of a wave beam field reflected in a turbulent atmosphere. It is shown that the effect of strengthening the amplitude level of the fluctuations depends on the diffraction size of the beam, whereas for phased fluctuations there is no such dependence. The dispersion and spatial correlation of amplitude and phased fluctuations are examined.

In connection with the development of optical locating and methods for long-range sounding of the atmosphere's parameters particular interest is being paid to the field characteristics of a reflected wave beam. Thus, in the works [1-3] the influence of a turbulent atmosphere on the median value of a reflected signal is investigated. Intensity fluctuations under various sized irradiators and reflectors are examined in [3-6].

The spatial correlation and time spectrum of the fluctuations' amplitude level of unrestricted flat and spherical waves are examined in [6-8] by a technique equivalent to the smooth perturbation method (MPV). In the work [9,10] with the aid of MPV an expression is derived for the second moments of a restricted wave beam field in the form of a three-stage integral and the effect of strengthening the dispersion of the fluctuations' amplitude level and phase for flat and spherica waves in the case of a Karmanov spectrum for the fluctuations in the refractive index is investigated.

In this work, for weak fluctuations we derive an integral concept convenient for digital analysis for the spatial characteristics of a reflected Gaussian wave beam field.

We shall define as Gaussian the distribution of a complex amplitude for a field in a plane with an outside aperture (x=0):

$$u(\rho)=\exp(-\rho^2/2\alpha^2), \qquad (1)$$

where $1/\alpha^2=1/\alpha_0^2+ik/F_0$; α_0 is the effective radius of the beam; F_0 is the curavature radius of the phased zone in the center of the aperture; $k=2\pi/\lambda$ is the wave number in free space; $\rho=|\rho|=(y^2+z^2)^{1/2}$ is the modulus of the radius-vector in the plane, perpendicular to the direction of the distribution OX.

We shall place a reflecting plane at a distance x=L from an emitter. Then such a route according to the distribution conditions will be equivalent to a doubled (with a length 2L) straight line on which the fluctuation index n(x, ρ) satisfies the condition

$$n(x,\ \rho)=n(2L-x,\ \rho). \qquad (2)$$

The expression for a complex phase ψ_1 of the beam field having passed through a turbulent atmospheric layer with a thickness of 2L, and taking into account the condition (2), may be written in the form [11,12]

$$\psi_L(2L,\ \rho)=\int_0^L dx\int_{-\infty}^{\infty}[e^{i\varkappa\rho\gamma}H(2L,\ \gamma)+e^{i\varkappa\rho\tilde{\gamma}}H(2L,\ \tilde{\gamma})]\,dn(\varkappa,\ x),$$

$$H(2L,\ \gamma)=ik\exp\left[-i\,\frac{\gamma(2L-x)}{2k}\varkappa^2\right],\quad \gamma(x)=\frac{1+iD(x)}{1+iD(2L)}, \qquad (3)$$

$$\tilde{\gamma}(x)=\gamma(2L-x),\ D(2L)=\frac{2L}{k\alpha_0^2}+i\,\frac{2L}{F_0}=a+ib,$$

dn(κ, x) is the spectral fluctuation amplitude of the refractive index

$$n(x,\ \rho)=\int e^{i\varkappa\rho}dn(\varkappa,\ x).$$

In the future for field fluctuations of the refractive index along the direction of propagation we shall use the Markovskiy approximation which is customary in these problems. Then for spectral refractive index amplitudes dn(κ, x) one may note [13]

$$\langle dn(\varkappa,x)dn(\varkappa',x')\rangle=2\pi\delta(\varkappa+\varkappa')\delta(x-x')\Phi_n(0,\varkappa)d\varkappa d\varkappa'dxdx', \qquad (4)$$

where $\Phi_n(0,\ \kappa)$ is a three-stage spectral fluctuation plane. Using the expressions (3) and (4) we derive the following formulas for correlative amplitude fluctuation levels $B_\chi(\rho_1,\ \rho_2)$, ($\chi=\mathrm{Re}\psi_1$) and phases $B_s(\rho_1,\ \rho_2)$, ($s=\mathrm{Im}\psi_1$):

$$B_{\chi,s}(\rho_1,\ \rho_2)=\bar{B}_{\chi,s}(\rho_1,\ \rho_2)+\tilde{B}_{\chi,s}(\rho_1,\ \rho_2),$$

$$\bar{B}_{\chi,s}(\rho_1,\ \rho_2)=2\pi^2\,\mathrm{Re}\int_0^{2L}dx\int_0^{\infty}\varkappa\Phi_n(\varkappa)[J_0(\varkappa Q)\,|H|^2\pm J_0(\varkappa P)\,H^2]\,d\varkappa, \qquad (5)$$

[Formula 5 continued on next page]

$$\breve{B}_{\chi,s}(\rho_1, \rho_2) = 2\pi^2 k^2 \operatorname{Re} \int_0^L dx \int_0^\infty \varkappa \Phi_n(\varkappa) \{ \pm e^{-i(\varkappa^2/2k)[\gamma(2L-x)-\tilde{\gamma}^* x]} \times$$
$$\times [J_0(\varkappa Q_1) + J_0(\varkappa Q_2)] - e^{-i(\varkappa^2/2k)[\gamma(2L-x)+\tilde{\gamma} x]} [J_0(\varkappa P_1) + J_0(\varkappa P_2)]\} d\varkappa,$$
$$Q^2 = \gamma^2(\rho_1^2 + \rho_2^2 - 2\rho_1 \cdot \rho_2), \quad P^2 = \gamma^2\rho_1^2 + \gamma^{*2}\rho_2^2 - 2\gamma\gamma^* \rho_1 \cdot \rho_2, \quad Q_1^2 = \rho_1^2\gamma^2 + \rho_2^2\tilde{\gamma}^{*2} -$$
$$-2\gamma\tilde{\gamma}^* \rho_1 \cdot \rho_2, \quad P_1^2 = \gamma^2\rho_1^2 + \tilde{\gamma}^2\rho_2^2 - 2\rho_1 \cdot \rho_2 \gamma\tilde{\gamma}, \quad Q_2^2 = \rho_1^2\tilde{\gamma}^{*2} + \rho_2^2\gamma^2 - 2\tilde{\gamma}\gamma^* \rho_1 \cdot \rho_2,$$
$$P_2^2 = \rho_1^2\tilde{\gamma}^2 + \gamma^2\rho_2^2 - 2\gamma\tilde{\gamma}\rho_1 \cdot \rho_2.$$

Here $\breve{B}_{x,s}(\rho_1, \rho_2)$ is the spatial function correlation for fluctuations in the level of the amplitude and phase of the field along the direct route of the line 2L which was derived in [12]; $J_0(z)$ is the zero-order Bessel function of the first generation. It may be shown that the expression (5) agrees with the results of the works [7,8].

In this manner, on a route with a reflection in the MPV approximation the secondary moments of a complex phase in a wave beam field are represented in the form of the sum of two components, one of which corresponds to the direct route, and the other is the result of a mutual correlation of the wave fluctuations in direct and reciprocal distributions through the very same discontinuities $n(x, \rho)$.

We shall perform further calculations for the turbulence spectrum $\Phi_n(\kappa)$, which corresponds to the Kolmogorov-Obukhov Law with consideration given to the inner scale l_0 [11]:

$$\Phi_n(\varkappa)\, A C_n^2 \varkappa^{-11/3} e^{-\varkappa^2/\varkappa_m^2}, \quad A = 0{,}033, \ \varkappa_m l_0 = 5{,}92, \qquad (6)$$

where C_n^2 is the structural characteristic of the refractive index fluctuations.

Substituting the spectrum (6) in the formula (5) and performing the integration of κ, we derive

$$B_\chi(\rho_1, \rho_2) = \bar{B}_\chi(\rho_1, \rho_2) + 7{,}068\sigma_{\chi\rho}^2(2L) \operatorname{Re} \int_0^{1/2} \Big\{ A_1^{5/6} \Big[{}_1F_1\Big(-\frac{5}{6}, 1; -\frac{\tilde{P}_1^2}{4A_1}\Big) + {}_1F_1\Big(-\frac{5}{6}, 1; -\frac{\tilde{P}_2^2}{4A_1}\Big)\Big] - C_1^{5/6}\Big[{}_1F_1\Big(-\frac{5}{6}, 1; -\frac{\tilde{Q}_1^2}{4C_1}\Big) +$$
$$+ {}_1F_1\Big(-\frac{5}{6}, 1; -\frac{\tilde{Q}_2^2}{4C_1}\Big)\Big]\Big\} dx,$$
$$A_1 = s^2 + \frac{i}{2}[\gamma(1-x) + \tilde{\gamma}x], \quad C_1 = s^2 + \frac{i}{2}[\gamma(1-x) - \tilde{\gamma}^* x],$$
$$s^2 = \frac{k}{\varkappa_m^2 2L}, \qquad (7)$$

$$\tilde{Q}_{1,2}=Q_{1,2}\left(\frac{k}{2L}\right)^{1/2},\quad \tilde{P}_{1,2}=P_{1,2}\left(\frac{k}{2L}\right)^{1/2},\quad \sigma^2_{\chi\rho}(2L)=0{,}308C_n^2k^{7/6}(2L)^{11/6},$$

${}_1F_1(\alpha,\beta,z)$ is the confluent hypergeometric function [14].

For an unrestricted flat wave in the expression (7) one may perform an integration along the route of propagation ($l_0=0$):

$$B_{\chi\rho}(\rho)=\overline{B}_{\chi\rho}(\rho)+\mathrm{Re}(i/2)^{5/6}[(5/11)\,{}_1F_1(-5/6,\ 1;\ 2i\rho^2)+(12/11)i\rho^2\,{}_1F_1(-5/6,\ 2;\ 2i\rho^2)],\quad |\rho_1-\rho_2|(k/2L)^{1/2}=\rho/2,\quad \sigma^2_{\chi\rho}=B_\chi=1{,}47\sigma^2_{\chi\rho}(2L). \tag{8}$$

In the case of a spherical wave it is well to perform an integration only for the case of $\rho_1=\rho_2=0$, which gives the following value for dispersion:

$$\sigma^2_{\chi c\phi}(0)=B_\chi(0,\ 0)=0{,}8\sigma^2_{\chi\rho}(2L).$$

The dependence of dispersion on the amplitude fluctuation levels $\sigma^2_\chi(0)=B_\chi(0,0)$ along the axis of a collimated beam (b=0) on the diffractive size of the emitting aperture is presented in figure 1. It is apparent that the general characteristic of fluctuation intensity dependence for a reflected signal is analogous to the case for direct propagation. We note that the maximum increase in dispersion in comparison with the normal route is observed for large values of the wave parameter α, and the least for the case of a flat wave. The variation for the internal turbulence scale under conditions $s^2\ll 1$ do not change this principle and only slightly flatten it.

The dependence of dispersion intensity fluctuations on the distance from the axis of the collimated beam are presented in figure 2. Here along the abscissa the distance which has been normalized to the size of Fresnel's zone is plotted from the observation point to the axis of the beam $\tilde{\rho}=\rho(k/2L)^{1/2}$. From the results presented it is apparent that the most

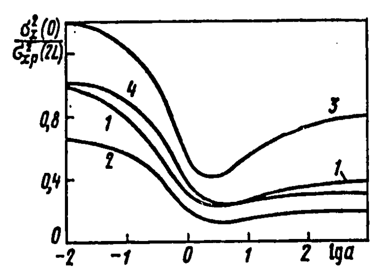

Figure 1. Dependence of Dispersion on Amplitude Level Fluctuations $\sigma^2_\chi(0)/\sigma^2_{\chi\rho}$ (2L) on the Axis of a Collimated Point (b=0) on the Wave Parameter α for a Straight Line (1,2) and a Line with Reflection (3,4) when $S_m^2=0.237\cdot 10^{-3}$ (1,3) and 0.1 (2,4)

rapid increase in dispersion by distance from the beam axis occurs in the case of narrow collimated beams (a=1). When decreasing or increasing the wave parameter from this value a smooth leveling of the fluctuations occurs. However, in the case of the Fraunhofer diffraction region ($\alpha \gg 1$) the dependence characteristic, beginning with $\alpha \approx 5$, changes to the opposite. The greatest reduction in dispersion fluctuations occurs in the extreme case of a spherical wave when, as it is possible to show, $\tilde{\rho} \ll 1$ the dispersion decreases according to the quadratic law:

$$\sigma^2_{\chi c\phi}=0,8\sigma^2_{\chi\rho}(2L)(1-\tilde{\rho}^2).$$

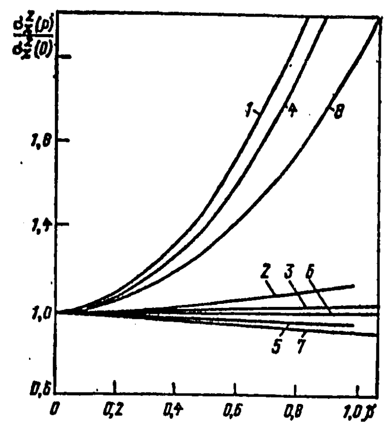

Figure 2. Normalized Dispersion of Amplitude Level Fluctuations $\sigma^2_\chi(\rho)/\sigma^2_\chi(0)$ for a Direct Line (1-3) and Lines with a Reflection (4-8) when a=1 (1,4), 10 (2,5), 0.1 (3,6), 10^8 7, $S_m^2=0.237\cdot 10^{-3}$) and 1 (8, $L_0=1.8$ m)

From the expression (5) it is not difficult to see that the relative contribution of spatial frequencies in the spectrum of refractive index fluctuations to the magnitude of amplitude and phase level fluctuations depends significantly on the position of the observation point relative to the beam axis. Thus, for example, when $\kappa \to 0$ is the integrand in the expression for $\sigma^2_\chi(\rho)=B_\chi(\rho, \rho)$ it is proportional to $\Phi_n(\kappa)\kappa^5$ for the case of a flat, spherical wave and a restricted point, when $\rho=0$. When removing the beam from the axis it becomes proportional to $\Phi_n(\kappa)\kappa^3$. In connection with this we also perform calculations with the spectrum in the form [13]

$$\Phi_n(\varkappa)=AC_n^2\varkappa^{-11/3}[1-e^{-\varkappa^2/\varkappa_0^2}]\,e^{-\varkappa^2/\varkappa_m^2},\ \varkappa_0 L_0=2\pi, \qquad (9)$$

where L_0 is the so called external turbulence scale.

This very expression is used in the calculation $B_s(\rho_1, \rho_2)$, when the most significant contribution is made by the large scale field fluctuations $n(x,\rho)$. Selection of the spectrum (9) was dictated by the convenience of performing corresponding calculations insofar as they are derived in this expression totally analogous to their own structural formulas (5). In addition, the results of the calculation for the displacements of the beam's center of gravity from the spectrum of atmospheric turbulence (9) agrees satisfactorily with the experiment [16].

When $\rho=0$ the results of the calculation, as one would expect, agree with the data presented in figure 1. In connection with this we note that the evaluations presented in [9] for the coefficient for strengthening the amplitude level fluctuations for the refractive index fluctuations of a Karmanov spectrum and for the Fraunhofer diffraction region relative to the internal turbulence scale under the condition $(\kappa_0^2 L/k) \ll 1$ have values which do not agree with our results.

As can be seen from the results of the calculation, in the case of narrow collimated beams (curve 6 in figure 2) the dispersion growth in the beam's cross section is significantly retarded in comparison with the case which corresponds to the spectrum (6).

The results of the calculation for the coefficient of amplitude level correlation are:

$$b_\chi(\rho_1, \rho_2)=B_\chi(\rho_1, \rho_2)/\sigma_\chi(\rho_1)\sigma_\chi(\rho_2),$$

when "the center of gravity" for the observation points is located in the center of the beam is presented in figure 3. As can be seen from these data, the general characteristic for dependence of the correlation coefficient on the diffraction size of the emitting aperture remains the same as on a straight line [15]. For narrow collimated beams ($\alpha=1$) this result agrees with the calculation presented in [5].

In the case of phased fluctuation from the expression (5) and (9) following integration of κ and x for flat and spherical waves one may derive the value

$$\sigma_s^2(0, 0)=B_s(0,0)=4{,}35C_n^2k^2\varkappa_0^{-5/3}\cdot 2L,$$

which exceeds by a factor of two the corresponding value for a straight line. As the digital calculation have shown, this result holds true also for a restricted point. The dispersion $\sigma_s^2(\rho)$ for a spherical wave depends on the position of the observation point relative to the source, analogous to the case of amplitude fluctuations, whereupon $(\lambda 2L)^{1/2}$ are changed to the value L_0.

The coefficient graphs for the spatial correlation $b_s(\rho)$ are presented in figure 4. As can be seen from these data, in the case of a spherical wave with a reflection (3) there occurs an increase in the correlation of the fluctuations compared to the direct line [9,10], whereas for a flat wave these values agree. For a reflected beam ($\alpha=1$) the calculation can be made successfully only to the values $\kappa_0\rho$, which correspond to the two diffractive beam sizes, where the correlation coefficient is close to unity (0.99).

28 FEBRUARY 1979 (FOUO 12/79) 2 OF 3

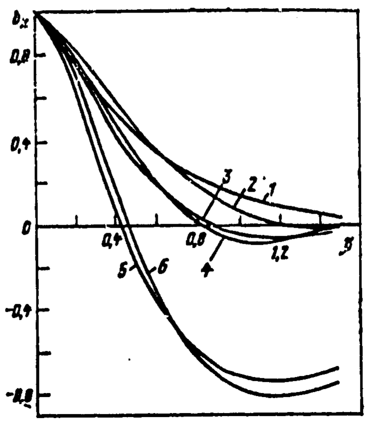

Figure 3. Correlation Coefficient for Amplitude Level Fluctuations $b_x(\rho)$ when b=0, S_m^2=0.237·10^{-3}, α=10^8 (1,2), 0 (3,4) and 1 (5,6) for a Straight Line (1,3,5) and Lines with a Reflection (2,4,6)

Thus, the statistical characteristics of the amplitude level and field phase of the signal which is reflected back from the flat mirror have the very same dependency characteristic on the diffraction size of the emitting aperture and the position of the receivers relative to the beam's axis which is on a straight line. However, in a number of cases there is a noticeable quantitative and evan qualitative difference which it is necessary to take into acccunt in corresponding experiments.

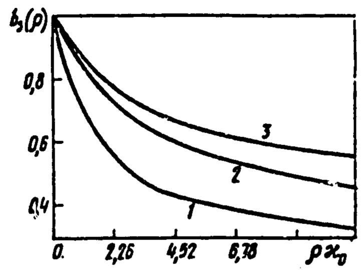

Figure 4. Phase Correlation Coefficient $b_s(\rho)$ for a Flat (1) and Spherical (2,3, l_0=0) Wave, For a Direct Line (1,2) and Lines with Reflection (1,3)

In conclusion we note that the derived results are dependent on the areas of so-called weak intensity fluctuations. Apparently for regions of strong fluctuations concrete results may be derived on the basis of a theory which is developed in [17,18].

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BIBLIOGRAPHY

1. Belen'kiy, M. S., and Mironov, V. L. KVANTOVAYA ELEKTRONIKA, No 5 (11), p 38, 1972

2. Vinogradov, A. G.; Kravtsov, Yu. A.; and Tatarskiy, V. I. IZVESTIYA VUZOV, SER. RADIOFIZIKA, Vol 16, p 1064, 1973

3. Vinogradov, A. G., and Kravtsov, Yu. A. "Sixth All-Union Symposium on Diffraction and Wave Propagation. Summary Texts of the Reports," Moscow - Yerevan, Vol 1, 1973, p 294

4. Belen'kiy, M. S., and Mironov, V. L. KVANTOVAYA ELEKTRONIKA, Vol 1, 1974, p 2253

5. Aksenov, V. P.; Banakh, V. A,; and Mironov, V. L. KVANTOVAYA ELEKTRONIKA, Vol 3, 1976, p 2266

6. Smith, J.; Pries, T.; Skipka, K.; and Hamiter, T. OPT. SOC. AMER., Vol 62, p 1183, 1972

7. Smith, J. OPT. SOC. AMER., Vol 63, p 1095, 1973

8. Smith, J., and Pries, T. APPL. OPTICS, Vol 14, p 1161, 1975

9. Lukin, V. P. "Summary Texts of the Reports from the 1st All-Union Conference on Atmospheric Optics," Tomsk, 1976, Part 1, p 129

10. Lukin, V. P. In the collection "Rasprostraneniye opticheskikh voln v neodnorodnykh sredakh," [Propagation of Optical Waves in a Nonuniform Atmosphere], edited by S. S. Khmelevtsova, Tomsk, 1976, p 137

11. Tatarskiy, V. I. "Rasprostraneniye voln v turbulentnoy atmosfere," [Wave Propagation in Turbulent Atmosphere], Moscow, Nauka, 1967

12. Ishimaru, A. RADIO SCIENCE, Vol 4, No 4, p 295, 1969

13. Tatarskiy, V. I., editor "Lazernoye izlucheniye v turbulentnoy atmosfere," [Laser Emission in Turbulent Atmosphere], Moscow, Nauka, 1976

14. Beytmen, G., and Erdeyn, A. "Vysshiye transtsendentnyye funktsii," [Higher Transcendental Functions], Moscow, Nauka, Vol 1, 1965

15. Mironov, V. L., and Patrushev, G. Ya. IZVESTIYA VUZOV. SER. RADIOFIZIKA, Vol 15. p 865, 1972

16. Mironov, V. L., and Nosov, V. V. IZVESTIYA VUZOV. SER. RADIOFIZIKA, Vol 17, p 247, 1974

17. Prokhorov, A. M.; Bunkin, F. V.; Gochelashvili, K. S.; and Shishov, V. I. UFN, Vol 114, p 415, 1974

18. Prokhorov, A. M.; Bunkin, F. V.; Gochelashvili, K. S.; and Shishov, V. I. PROC. IEEE, Vol 63, p 790, 1975

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OUTPUT DISK AMPLIFIER STAGES

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/Text/ The results are presented of studies into the energy characteristics of disk amplifiers with light diameters of 90 and 120 mm. An inverse population distribution has been studied in the cross section of the disk amplifiers and over the disk thickness. Dependencies have been investigated of the disk amplifier gain on the pump energy. A comparison has been made of the gain efficiencies of silicate glass GLS1 and phosphate glass GLS21. A greater influence of superluminescence and parasitic oscillation on the stored energy value has been found experimentally at high pump energy values for phosphate glass, than in the case of silicate glass. Results are presented of studies of the influence of edges and sizes of the active elements on the disk amplifier stage efficiency.

The best approach in building powerful lasers to superheat plasmas appears to be one with a minimum number of holes, resulting in larger laser output apertures. Either disk amplifiers /1-5/ or solid state laser amplifiers /6,7/ can be used as output stages in such devices. The former have some advantages over the latter in the efficiency of the pump system. What is more, a disk amplifier, in contrast to solid state laser amplifiers, is insensitive to thermooptic distortions, permits the reception of a uniform distribution of stored energy at aperture, and possesses higher self-focusing thresholds, than a continuous, active media /8/. Noteworthy, too, is the fact that the use of absorbent coatings on the disk edges enables the suppression of parasitic oscillation and superluminescence in disk amplifiers even with very large light apertures /9/. What is more, the efficiency of disk amplifier pump systems can almost be brought up to the pump efficiency of rod amplifiers. In view of these facts, disk amplifier stages appear most promising for laser induced thermonuclear fusion.

The results of our studies of 120 mm diameter disk amplifiers, made of silicate neodymium glass GLS1 are presented in [5]. This amplifier pump system was selected in accordance with the data presented in [10], which showed that when the flash lamp lies transverse relative to the amplifier axis and extra planar reflectors are used, a high uniform pump occurs at amplifier aperture, and the pump system achieves greater efficiency than in designs in which the flash lamp is tightly wound around the disk lengthwise and in spirals, as is done in a number of foreign laboratories.

The present work summarizes the results of studies into the energy characteristics of improved 90 and 120 mm diameter disk amplifiers made of phosphate neodymium glass GLS21. These disk amplifiers are used as output stages for amplifying a 6-stage laser [11]. The neodymium glass was chosen for the disk amplifiers because the thermooptic constants of this glass are extremely small, thereby ensuring a high directivity of laser radiation [12]. Also, this glass has an appreciably larger cross section for stimulated transitions, than, for example, GLS1 glass.

Features of the Amplifier Pump System

The disk amplifiers, examined here, have in essence preserved the features of the 120 mm diameter amplifiers described earlier [5]. They are made of four modules (two active elements—disks—mounted in each). The disks, as before, are configured as eight-sided plates, 23 mm thick, and oriented at Brewster's angle in a zigzag across the axis of the module. The pump is accomplished by xenon flash lamps, mounted perpendicular to the optic axis of the module on the outside surface of the disks. The flash lamps are set in silver-plated, semitubular glass reflectors. Counter reflectors are set on the top and bottom inner surfaces of the module.

Sixteen flash lamps are set in each amplifier module, 120 mm in diamter. Here the flash lamps, when employed, can impart to the eight-disk amplifier 200 kJ of electrical energy, stored in the capacitors. Twelve similar lamps with a shorter discharge gap are used to pump a 90 mm diameter module. The maximum pumping energy of an amplifier, consisting of four modules, is 100 kJ. The pulse duration of a circuit discharge reaches 450 Maxwell at a 0.5 level off the peak value.

The glass elements in the disk amplifier have been mounted to shut off the ultraviolet component of the pump radiation. The need to shield the disk chamber cavity from ultraviolet radiation is related to the very intensive absorption by atmospheric oxygen of vacuum ultraviolet radiation [13, 14], which partially escapes through the quartz tubing of the flash lamp, heating the air as a result and possibly causing optical distortions in the amplified beam [15].

Methodology, Experimental Results and Analysis

1. Stored energy distribution in the disk amplifier aperture and over disk thickness. A photographic method was used to determine the density distribution of stored energy (inverse population distribution) along the amplifier aperture. The distribution was recorded on a 1,054 micrometer wave at small disk amplifier pump levels. The photographs were taken in linearly polarized light. In this way pump radiation, reflected from the working surface of the disks, was eliminated. This had to be done, otherwise substantial distortions would have been injected in the true distribution.

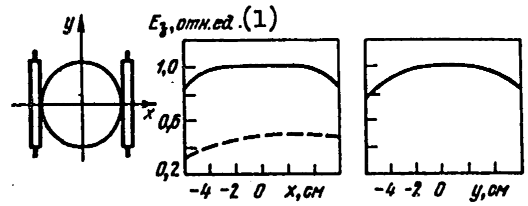

Figure 1. Stored energy density distribution along 120 mm diameter amplifier aperture. (1) relative unit

The main results of measuring the stored energy density distribution E_z over a 120 mm diameter amplifier aperture are shown in Fig. 1. The corresponding distributions along the X and Y axes, plotted on the schematic representation of the disk amplifier, are presented here. The distributions in other directions, through the center of the amplifier aperture, are not presented, but are close to those in Fig. 1. Apparently, disk amplifiers with a large diameter assure highly uniform stored energy density distributions at aperture. The steep slopes at the edges of the aperture make up in all 15-20 percent of the distribution.

Similar results were also obtained for 90 mm diameter disk amplifiers.

Figure 2 shows the results of measuring the density distribution of stored energy over disk thickness. These results were obtained by a photoelectric method. The distributions were obtained in the direction of the minor axis of the disk for a section close to its center. In so far as the size of stored energy in the disk's center for the GLS21 glass amounts to approximately 50 percent of the energy stored near its working surfaces (30 percent pump energy in the absorption bands of the glass passes through the disks without being absorbed), one should expect an increase in stored energy with an increase in concentration of activators in the glass or in disk thickness. The stored energy density distributions over the disk thickness appear justifiable for the central part. There distribtuions must become somewhat asymmetrical the further removed from disk center. This may be associated with some illumination irregularity of the disk surfaces along the major axis, and also with a change in the mean angle of incidence of pump radiation on the various sections of the working surfaces of the disks. In Figure 1 the broken line shows the inverse population distribution across the amplifier when the flash lamps, located on one side of the disk, are operating.

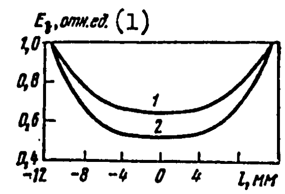

Figure 2. Stored energy density distribution over disk thickness for GLS1 glass (1) and GLS21 glass (2). (3) rel. unit

2. Disk amplifier gain coefficients and controlling parasitic oscillations. Measuring disk amplifier gain was accomplished with the aid of a single-mode monopulse laser, made of phosphate neodymium glass GLS22. The amplified pulses lasted about 20 nanoseconds; the beam's diameter at disk input was 5 mm; the energy density did not exceed 50 mJ/cm^2 (corresponding to the amplification of a weak signal). The amplified beam was emitted near the optic axis of the disk amplifiers.

The results of measuring the disk amplifier gain for a 120 mm diameter are presented in Figure 3. The characteristic shape of curve 1 (a plateau, beginning with a specific pump energy of 35 J/cm^3), obtained for the disks with polished edges, definitely indicates the generation of parasitic oscillation. The course of curve 2, corresponding to disks with a coating that absorbs 1.06 micrometer wavelength light, graphically demonstrates the effectiveness of the coating. At maximum pump energy the increase in gain, as Figure 3 shows, reached 37 percent. However, here also superluminescence plays a noticeable role, causing losses in the inverse population distribution. This can be seen in curves 2 and 3. The last measurement was obtained with partial screening of the disks by shutters, similar to those used in [5].

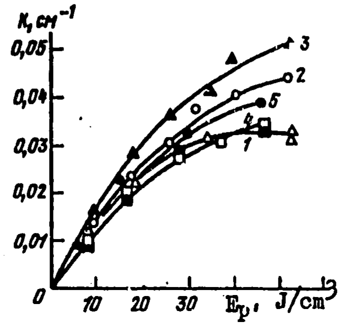

Figure 3. Gain coefficient K as a function of pump energy density E_p for 120 mm diameter (1-3) and 90 mm diameter (4,5) disk amplifiers. 1,4 (□)—polished edge disks; 2,4 (■)—coated edges; 3,5—shuttered surfaces.

Figure 3 also shows the gain measured in 90 mm diameter disk amplifiers. With the polished edge disks here, in contrast to the previous case, no plateau appeared in the experimental curve, indicating an absence of parasitic oscillation. Further studies showed that the application of an absorbent coating on the disk edges has no effect: the experimental points fell on the previous curve. The gain coefficient achieved here was less than the maximum gain in the 120 mm diameter disk amplifiers and insignificantly higher than the gain, at which the parasitic oscillation threshold was reached. The fact that the overall dimensions of the large and small disks differ by approximately a factor of 1.3, explains the absence of parasitic oscillation in the 90 mm diameter disk amplifiers. In truth, for parasitic oscillation to appear in the disk amplifier the gain must be 1.3-fold greater than the threshold gain coefficient of the larger amplifier, which does not occur.

The lower gain values in the 90 mm disk amplifier in comparison with the larger amplifier, obviously, cannot be associated with the losses due to superluminescence. As a comparison of curves 4 and 5* of Figure 3 shows, superluminescence reduces very little the level of inversion for small disk amplifiers.

*In this case shutters with the smallest practical size were used: 4.5x 4.5 cm. Further reduction in outlet size would cause a reduction in pump at aperture center—at point of the amplified beam's transit.

It is assumed that the lower efficiency of the 90 mm diameter amplifier is caused by the lower efficiency of its flash lamps due to the relatively larger inert matter in these lamps [16, 17]. It should be noted that the bending of curve 3 (Fig. 3), perhaps, is also explained, along with the losses due to superluminescence, by the drop in efficiency of the flash lamps with an increase in charge. It was observed that the lower efficiency of the smaller lamps can be associated with relatively greater cross-sectional losses of charge emission for these lamps, so long as these losses are proportional to the ratio of the cross-sectional areas of the discharge column to its surface area.

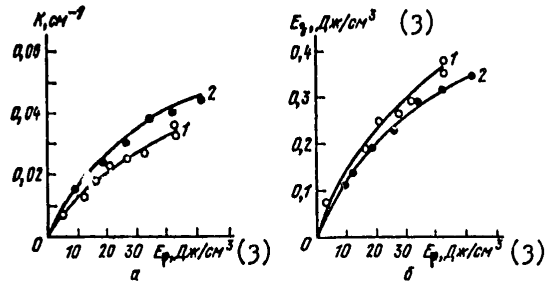

Figure 4. Gain coefficient K(a) and stored energy density E_z(b) as functions of pump energy density E_p for GLS1 (1) and GLS21(2) glass. (3) J/cm^3

3. Comparison of the gain efficiency of phosphate and silicate neodymium glass. For GLS1 glass the cross section of stimulated transitions equals 1.8×10^{-20} cm, for GLS21—2.5×10^{-20} cm [18]. As Figure 4 shows, a large gain is achieved with GLS21 glass, while with GLS1 there is a noticeably large stored energy density. This result is explained by the fact that phosphate GLS21 glass has a shorter upper laser life span than GLS1 glass. Moreover, the former glass experiences greater losses because of superluminescence, so long as the losses are proportional to σ^2. This result clearly indicates that with large energy densities of the input signal, GLS1 glass must be more advantageous energy wise, than GLS21. Using the results, presented in [19], one can conclude that for a signal of approximately 10^{-8} seconds duration, equalization of gains will occur with an input signal of about 4.5 J/cm^3. For subnanosecond signals gain equalization will occur, obviously, at somewhat smaller input energy densities. All the same, because of comparatively low thresholds of small-scale self-focusing in the

neodymium glass (3-5 hectowatts/cm^2 [20], i.e., for example, 1.5-2.5 J/cm^2 with a pulse duration of 5×10^{-10} sec), such a gain mode is hardly suitable for use. This leads one to conlude that the use of GLS21 glass in certain disk amplifiers is more advantageous energy wise than the use of GLS1 glass.

It should be noted that shortening the length of the pump signal τ_p for disk amplifiers made of GLS21 glass (to $\tau = \tau_p$, where τ is the upper laser life span) must result in some increase in the stored energy level.

4. Subnanosecond signal amplification. Disk amplifiers were also tested for amplification of a subnanosecond signal in a device consisting of a driving oscillator and several amplification stages. The driving oscillator was a selfsynchronized laser made of GLS22 glass and an internally resonating Fabry-Perot interferometer. A Pockel's cell at oscillator output isolated a single pulse of ~0.6 ns duration from the light beam. The pulse was amplified in a diverging beam with 10^{-2} rad absorption, then collimated and sent to the disk amplifier input. The incident beam had a uniform energy distribution, with a 10 mm diameter. Moreover, the mean energy density in the beam was about ~0.6 J/cm^2. The results of these measurements are shown in Figure 5. Here, for comparison sake, are shown the gain curves for a weak signal. As the data shows, computed with an allowance for the stretching of the luminescence lines of the neodymium glass, the corresponding curves agree quite well with each other.

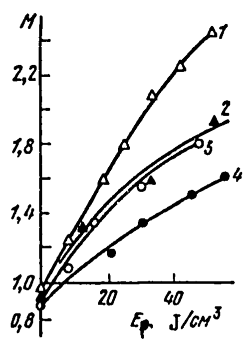

Figure 5. Gain M (ratio of output energy to input energy) as a function of pump energy density E_p in disk amplifiers of 120 mm (1,2) and 90 mm (3,4) diameter for a weak signal (1,3) and for input density of a ~0.6 J/cm^2 signal (2,4) of $\sim 6 \times 10^{-10}$ sec duration.

Conclusion

The disk amplifiers examined here perform as suitable efficiency pump systems. The table presents for comparison the experimental data obtained on the efficiency (E_z/E_p) of the pump systems of the three types of amplifiers. The results presented here are not the ultimate energy characteristics of disk amplifiers. Definite reserves for increased disk amplifier efficiency lie in the choice of optimum concentration of activators in the glass, in the development of more efficient flash lamps (especially for 90 mm diameter disk amplifiers), in improved absorbent edge coatings, in increasing the conversion ratio for converting electric energy, stored in the capacitor battery, into light energy, i.e., the choice of optimum pulse form and duration of discharge. Further constructive improvements of the entire disk amplifier pump system are also feasible.

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Тип усилителя (1)	Марка стекла (2)	$E_п$, Дж/см³ (3)	$E_з$, Дж/см³ (4)	$E_з/E_п$, % (5)
(6) Стержневой, Ø 15 мм (ГОС-1001)	ГЛС1 $\sigma = 1{,}8 \times 10^{-20}$ см²	25	0,52	2,1
(7) Прямоугольный параллелепипед, 40×240×630 мм*	ЛГС 247-2 $\sigma = 1{,}6 \times 10^{-20}$ см²	25	В центре — 0,23, вблизи края 0,42, усредненная по апертуре 0,28 (9)	1,12
(8) Дисковый, Ø 120 мм	ГЛС1 $\sigma = 1{,}8 \times 10^{-20}$ см²	25	0,3	1,14

(10) * Накачка осуществлялась 36 лампами с разрядным промежутком 250 мм. Распределение запасенной энергии по поперечному сечению определялось как с помощью фотографической методики, так и с помощью зондирования узким пучком лазера в режиме слабого сигнала.

Key:
1. Amplifier type
2. Type of glass
3. E_p, J/cm³
4. E_z, J/cm³
5. E_z/E_p, %
6. Rod
7. Solid state
8. Disk
9. In center—0.23, near edge 0.42, mean over aperture 0.28
10. Pump is accomplished by 36 flash lamps with 250 mm discharge gap. Stored energy distribution in the cross section was determined by photographic techniques and low level laser beam recorder.

BIBLIOGRAPHY

1. McMahon, J. M.; Emmett, J. L.; Holzrichter, J. F.; Trenholme, J. B. IEEE J. QE-9, 1973, p 922.
2. Mace, P. N.; Tanner, R. L. IEEE J. QE-10, 1974, p 267.
3. Soures, J.; Kupman, S.; Hoose, J.; APPL. OPTICS, Vol 13, 1974, p 2081.
4. Yoshida, K.; Sasaki, T.; Suzuki, K.; Yamanaka, T.; Yamanaka, C. TECHNOL. REP. OSAKA UNIV., Vol 24, 1974, p 83.
5. Alekseyev, V. N.; Mak, A. A.; Pivinskiy, Ye. G.; Sedov, B. M.; Starikov, A. D.; Tsvetkov, A. D. KVANTOVAYA ELEKTRONIKA, Vol 3, 1976, p 226.
6. Kalinin, Yu. A.; Mak, A. A.; Stepanov, A. I. ZhTF, Vol 38, 1968, p 1108.
7. Anan'yev, Yu. A.; Sirozetdinov, V. S., Chernov, V. N.; Shorokhov, O. A. KVANTOVAYA ELEKTRONIKA, N. G. Basov, editor, No 3 (15), 1973, p 115.
8. Baranova, N. B.; Bykovskiy, N. Ye.; Zel'dovich, B. Ya.; Senatskiy, Yu. V. KVANTOVAYA ELEKTRONIKA, Vol 1, 1974, p 2450.
9. Guch, S. APPL. OPTICS, Vol 15, 1976, p 1453.
10. Vakhmyanin, K. P.; Korolev, V. I., et alia. OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', No 6, 1975, p 73.
11. Alekseyev, V. N.; Burtsev, V. A.; Glukhikh, V. A.; Gorokhov, A. A. et alia. TEZISY DOKL. VII VSESOYUZ. KONF. PO KOGERENTNOY I NELINEYNOY OPTIKE [Theses Reports. VII All-Union Conference on Coherent and Non-linear Optics], Vol 2, Tbilisi, Metsniyereba, 1976, p 236.
12. Mak, A. A.; Mit'kin, V. M.; Soms, L. N., et alia. OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST', No 9, 1971, p 42.
13. Watanabe, K.; Inn, E. C. Y.; Zelikoff, M. J. CHEM. PHYS., Vol 21, 1953, p 1026.
14. Elton, R. C. J. NUCL. ENERGY C., Vol 6, 1964, p 401.

15. Linford, G. J.; Chan, H. H.; Glaze, J. A.; Layne, C. B.; Reiner, F. APPL. OPTICS, Vol 14, 1975, p 3057.

16. Vlasov, Yu. N.; Ikonnikov, V. P.; Rozanov, A. P.; Starikov, B. V. SVETOTEKHNIKA, No 12, 1970, p 23.

17. Basov, Yu. G.; Makarov, V. N.; Narkova, G. I.; Tokareva, A. I.; Usova, V. M. RADIOTEKHNIKA I ELEKTRONIKA, Vol 19, 1974, p 1702.

18. Guba, B. S.; Raba, O. B. TEZISY DOKL. XI KONF. MOLODYKH SPETSIALISTOV, Leningrad, GOI, 1976, p 92.

19. Ibid., p 93.

20. Zherikhin, A. N.; Matveyets, Yu. A.; Chekalin, S. V. KVANTOVAYA ELEKTRONIKA, Vol 3, 1976, p 1585.

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Zhelikhovskiy, Aleksandr Alanol'yevich. Junior Scientific Staff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Principles of Organization of the PIONER Dialog Optimization System."

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Kapitonova, Yuliya Vladimirovna. Doctor of Physical and Mathematical Sciences, laboratory manager, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "ANALITIK-74."

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Korzhova, Valentina Nikolayevna. Graduate student, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Optimization of Algorithms for Evaluating the Mathematical Expectation of a Random Valuable Under Various Modes of Data Processing."

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Kornilova, Lyudmila Yevgen'yevna. Candidate of Physical and Mathematical Sciences, Instructor, Kiev State University. "Certain Properties of Antichains of Partially Ordered Sets."

Kres, Leonid Nikitich. Group leader, Scientific and Technical Society, Gorsistemotekhnika [expansion unknown], Kiev. "ANALITIK-74."

Krivoy, Sergey Luk'yanovich. Graduate student, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Interactive Data Structures Processing."

Kuk, Yuriy Vasil'yevich. Junior Scientific Staff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "A Generalization of the Neumann-Pierson Lemma in the Theory of Signal Recognition."

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Lyaletskiy, Aleksandr Vladimirovich. Junior Scientific Staff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "On Certain Deductive Features of a System for Processing Mathematical Texts."

Mikhaylov, Valeriy Mikhaylovich. Leading Designer, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Representation of Surfaces in Automatic Design Systems."

Nikitin, Anatoliy Nikolayevich. Junior Scientific Staff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Structural Analysis of Analog-Digital Converter Algebra."

Nikolenko, Vladimir Nikolayevich. Graduate student, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "On Transformations of Asynchronous Logical Circuits."

Norkin, Vladimir Ivanovich. Engineer, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Nonlocal Algorithms for Minimization of Non-differentiable Functions."

Nurminskiy, Yevgeniy Alekseyevich. Candidate of Physical and Mathematical Sciences, Senior Scientific Stsff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "On the Differentiability of Set-Valued Mappings."

Pogrebinskiy, Semen Beniaminovich. Candidate of Technical Sciences, Deputy Director, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "ANALITIK-74."

Rappoport, Iosif Simovich. Engineer, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "On a Linear Several-Player Differential Game with Limited Control Resources."

Savchak, Oleg Nikolayevich. Leading Designer, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "ANALITIK-74."

Skopetskiy, Vasiliy Vasil'yevich. Candidate of Physical and Mathematical Sciences, Senior Scientific Staff Member, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "On an Iteration Method for the Solution of Boundary Value Problems."

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Stogniy, Anatoliy Aleksandrovich. Corresponding Member, Ukrainian SSR Academy of Sciences, Deputy Director, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "ANALITIK-74."

Syrov, Viktor Valentinovich. Leading Designer, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Optimal Coding of Microcommands in the Representation of Microoperations by Elementary Conjunctions."

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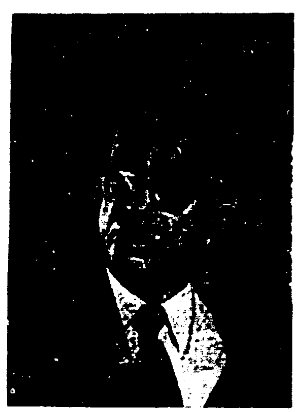
Tsaryuk, Nikolay Pavlovich. Leading Designer, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "ANALITIK-74."

Sheverda, Oleg Nikolayevich. Leading Designer, SKB MMS, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Resource Control in Data Processing Systems for Full-Scale Experiments."

Shilo, Vladimir Petrovich. Engineer, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Application of Stochastic Programming Methods to Problems of Control of Diffusion Processes."

Yatsenko, Yuriy Petrovich. Graduate student, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev. "Simulation of Certain Oscillatory Bioprocesses."

[photographs of contributors]



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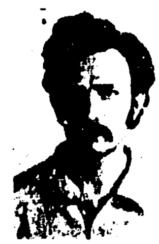

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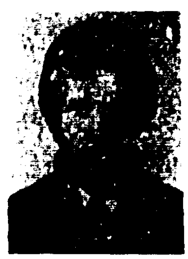

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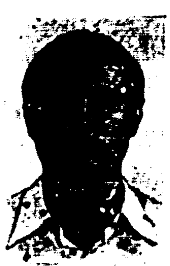

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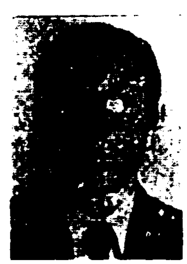

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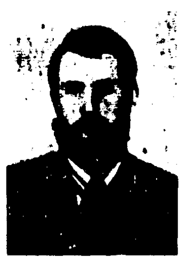
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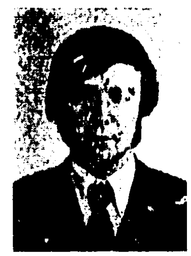
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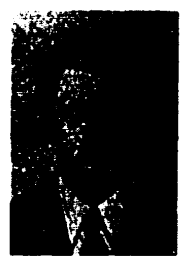
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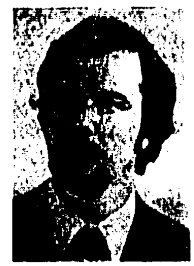

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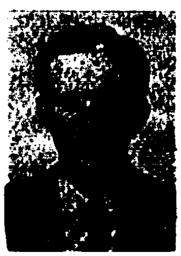

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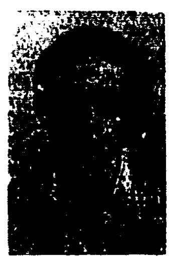

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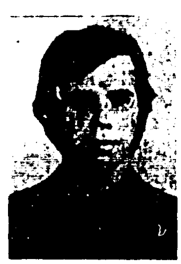

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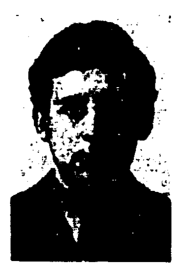

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SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

NIKOLAY NIKOLAYEVICH PONOMAREV-STEPNOY

Moscow ATOMNAYA ENERGIYA in Russian Vol 45, No 6, Dec 78, p 465

/Text/ Professor Nikolay Nikolayevich Ponomarev-Stepnoy, Doctor of Technical Sciences, deputy editor-in-chief of the journal "Atomic Energy" and head of the Department of High-Temperature Energetics of the Institute of Atomic Physics imeni I.V. Kurchatov commemorated his 50th birthday 3 December 1978.

N.N. Ponomarev-Stepnoy is a representative of the Soviet school of atomic reactor engineering founded by I.V. Kurchatov and A.P. Aleksandrov. His contributions to the scientific program of establishment of the high-temperature reactors program in the Soviet Union include several theoretical-calculation studies of the physics of high-temperature reactors, physical designing of them and development of programs of experimental studies of fundamental physical problems of high-temperature energetics. He is participating in drawing and design studies directed toward development of prototypes of reactors for technological purposes, radiation chemistry, a fast breeder reactor with a helium coolant and others.

Nikolay Nikolayevich is involved in studies on the direct conversion of energy. He is one of the scientific directors and developers of the world's first high-temperature breeder reactor "Romashka." He has devoted much time to the study of different aspects and peculiarities of reactors -- thermo-emission generators.

His scientific authoritativeness, benevolence, simplicity and exactingness have enabled Nikolay Nikolayevich to unite the ranks of the collective of researchers directed by him at the Department of High-Temperature Energetics. He has a vast store of energy and efficiency which inspire those around him. It was not without reason that Vasilevich Kurchatov called him a "four-wheel drive."

Since 1956, Nikolay Nikolayevich has been teaching at MAI /Moscow Atomic Institute/ as a professor of one of the Chairs. He works with great creative effort on the editorial board of the journal "Atomic Energy" and on the editorial council of Atomizdat.

He has been awarded the Order of the Red Banner twice and other medals.

The board of the Institute of Atomic Energy imeni I.V. Kurchatov and the editorial staff of the journal "Atomic Energy" congratulate Nikolay Nikolayevich on his 50th birthday and wish him further creative successes.

2791
CSO: 1870

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

SOVIET-ITALIAN SEMINAR ON THE STUDY OF PLASMA IN TOKAMAKS

Moscow ATOMNAYA ENERGIYA in Russian Vol 45, No 6, Dec 78, pp 472-473

/Article by L.G. Golubchikov/

/Text/ Results of developments and research on the Soviet tokamaks T-10, T-4, TM-3 and T-7 and the Italian tokamak FT were discussed at a seminar held in Frascati (Italy) 19-23 June 1978. The sessions met in a new building which houses the FT tokamak so that, in intermissions, it was possible to approach the control desk and observe directly the operational characteristics of the device on a display screen.

The FT device is an averaged size tokamak (R = 83cm, a = 21cm) with a strong toroidal field (H = 100 kE) and power supply from an 120 MW percussion generator. The device is equipped with a modern diagnostic complex, a system of automatic collection of data and is intended for operation with a frequency of 1 pulse in 10 minutes. At present, experiments are being conducted with liquid nitrogen cooled toroidal coils with toroidal field intensity up to 65 kE. The maximal attained L_{pl} discharge current is 440 kA, however there has been no success yet in achieving regimes without current disruption within 2 - 25ms after the beginning of the pulse.

The device has a bellows-type liner made from stainless steel and a molybdenum diaphragm which may be replaced without disturbing the vacuum conditions within the vacuum lock. The initial vacuum in the chamber is 2.10^{-8}mm mercury column in the warm up state and 2.10^{-9}mm mercury column in the operating regime. Induction heating up to 300°C is used to remove water from the walls of the liner. The high initial vacuum is not a guarantee of a low level of oxygen in the discharge but guarantees slow formation of oxides on the walls. Additional purification with the help of low temperature aging discharge of 3 -4 kA at a field intensity of 1 kE provided an increase of plasma density to 10^{14} cm^{-3} and reception of rather low Z_{ef} values. It is important to emphasize the inadequate repetition of discharges especially for such parameters as intensity and response at the time of the low energy, X-ray radiation signal. For a typical discharge of the FT with $H_z = 60$ kE and $I_{pl} = 406$ kA ($q \simeq 3.5$) is obtained $n_e(r) \simeq 1.7 \cdot 10^{14}(1 - r^2/a^2)$ cm^{-3}, $T_e(r) \simeq (1 - r^2/a^2)^2 \times 10^3$ eV, $T_i(0) \simeq 600$ eB, $\tau_E \simeq 10$ ms, $Z_{ef} \simeq 2$. The shape of the electron temperature T_e is typical for discharges with dominating light admixtures.

After completion of these programs of studies on joule warm up, experiments will be started on supplementary heating of plasma at the frequency of lower hybrid resonance, planned for the end of 1979. At the first stage, the power of high-frequency heating will constitute 0.5 MW and, if successful, it may be increased to 1 MW.

In Fraskati, the delegation visited laboratories occupied in the development of super conducting magnetic systems. Now the plans of the laboratory are being reoriented to the preparation for creating superconducting systems for the tokamak. Basic problems at present include the development of superconducting materials for realization of powerful magnetic fields in large scale devices and the study of a circulation method of cooling the superconducting magnetic systems. Laboratory associates prepared a large batch of conductor based on NbAl with critical current of 60 A in a field of 54 kGs and 20A at 110 kGs. Studies showed that such a conductor maintains its properties with relative prolongation of 0.4 - 0.5 percent, that is, twice as much as that for niobium-stannic superconductors.

After finishing the seminar, the delegation visited the laboratory of plasma physics at Milan University, where the "Tor" tokamak (R = 55cm, a = 14.5 cm, H = 10 kE) is being set up. The device was designed and constructed in Kalem laboratory (Great Britain). The first discharge experiments are being conducted and magnetic fields are being corrected. The device is being developed for teaching students specializing in plasma physics. There is proposed, in 1979, experiments in super high frequency heating of plasma at the frequency of electron cyclotron resonance with the help of gyrotrons of the "Varian" Firm (power 100 kVt, wave length ~1 cm).

2791
CSO: 1870

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

ALL-UNION SEMINAR ON THE TECHNOLOGY OF PROCESSING ORES OF RARE, TRACE AND RADIOACTIVE ELEMENTS

Moscow ATOMNAYA ENERGIYA in Russian Vol 45, No 6, Dec 78, pp 468-469

/Article by V.A. Pchelkin and E.A. Semenova/

/Text/ Participants in the seminar held in Moscow in May-June 1978 included specialists of organizations and enterprises of the Ministry of Ferrous and Non-ferrous Metallurgy, the Ministry of Geology, the Ministry of the Chemical Industry and the Ministry of Colleges of the USSR and the AS USSR.

Academician B.N. Laskorin presented the opening address. He discussed the development of studies directed toward the complex use of reprocessed raw material because of the creation and introduction of flow charts of the extraction of non-ferrous, rare, trace and radioactive elements (molybdenum, copper, vanadium, zirconium, gold, rare earth metal (REM), strontium, fertilizer and fodder phosphates) and described the modernization of production because of the introduction of new types of materials, equipment and constructions. He described the wide-scale introduction of pressure leaching, non-filtration sorption methods, membrane technology and the creation of new ionites and flocculants of new equipment and improvement of environmental protection.

Five review articles were presented at the first plenary session. I.P. Smirnov and S.A. Pirkovskiy described the use in autoclave technology of horizontal 4-chamber autoclaves with mechanical agitators and vertical autoclaves with pneumatic pulp agitators. They recommended the use of alloyed steel and commercial grade titanium as construction materials.

Sorption methods of isolating valuable associated elements during processing of ores facilitate direct extraction of soluble components from pulp of any density and guarantee the required degree of concentration and purification (discussed in addresses by B.N. Laskorin and L.I. Vodolazov). As a result of introduction of these methods into the industry, the productivity of plants was increased 1½ - 3 times and the extraction of useful components increased by 5 - 10 percent. Most of the industrial operations harmful to health were eliminated and there was created a continuous technology which ensures complete complex automation with the use of the simplest and most accessible means of control and regulation.

Processes based on the use of selective membranes make possible refinement, separation, concentration and neutralization of different industrial solutions of waste waters, the intensification of leaching, oxidation, reduction and isolation of metals, the separation and enrichment of gas mixtures were described in an address by N.M. Smirnov. In combination with other methods, they permit the utilization of valuable components, their repeated use and the avoidance of discharge of chemical reagents into the atomosphere.

I.A. Yakubovich in discussing further improvement of separation of pulp, washing of settlings and filtering of solutions in hydrometallurgy, emphasized the use of polyacrylamide and other types of flocculants and also the development of new means and methods of intensification of these processes. There is special interest in floto-flocculation filtering of solutions and also in the apparatus with a fluidized bed in a liquid-solid dispersed particles system used for these purposes. The wide extension of filtering diaphragms based on synthetic materials opened prospects for improvement of separation processes both in terms of quantity and in terms of quality.

D.I. Skorovarov and others, in their addresses, gave special attention to the use of non-combustible diluents in extraction processes. The use as a diluent of extrahents of tetrachloro-ethylene in flow charts of extraction purification and extraction of certain non-ferrous and rare metals showed the advantages of the developed charts over charts which involve the use of kerosene (increase of the maximal capacity of the extrahent, increase of the effectiveness of extraction recovery and others). The use of hydroxy-oximes and ethers of arylsulfonic acids were recommended for extraction of copper, cobalt and nickel. Di (2-ethylhexyl) phosphoric acid and the thallium-iodine form of tributylphosphate were proposed for extraction of indium. Recommendations were proposed for extraction of gold from spent electrolytes with the use of trialkylamines and mixtures of them with neutral organophosphoric compounds or petroleum sulfoxides. There was a proposal to extract tin from solutions of processing cassiterite ores with the use of solutions of tributylphosphate, trialkybenzylammoniachloride and trialkylamine and metal which tends to the formation of iso or hetero-polycompounds (molybdenum tungsten) -- by trialkylamines. The use of a mixture of trialkylamine and tributylphosphate was recommended for extraction of vanadium.

One of the effective methods of processing low-grade phosphorites is liquid extraction by organic solvents which permits production of both pure phosphoric acid and industrial salt and high-quality fertilizers. The use of inexpensive and readily available solvents produced by the industry and the effectiveness of the process make it extremely promising. The seminar included discussions of an extraction technology of processing low-grade phosphorites which makes possible the extraction and utilization of such valuable components as fluorine, raro earth elements, uranium, strontium and scandium.

Methods of producing rare earth master alloys on a silicon base for modification of cast irons and steels have been developed. A carbothermal method of producing master alloys has been mastered on an experimental industrial scale. Combined oxides of rare earths are used for reduction. The oxides are preliminarily briquetted or shaped from coal. The slag-free, continuous process is conducted in standard ferro-alloying furnaces. The extraction of rare earth metals in the master alloy constitutes 95 percent. The composition of the master alloy: rare earth metals -- 30-60 percent, silicon - 50-60 percent and the remainder iron. It was noted, at the seminar, that a master alloy containing magnesium is especially promising for inoculated cast iron.

There has been developed berillium alloys with a higher combination of mechanical and technological parameters as compared to standard brands. Micro-alloyed magnesium permitted significant improvement of properties not only of widely used high alloy brands of berillium bronzes with berillium content of 1.8 - 2.1 percent, but was found to be effective also in alloys with reduced berillium content (up to 1.6 - 1.8 percent).

The industrial introduction of hydrometallurgical processes was described by representatives of the Dnieperpetrovsk Metallurgy Institute, the Zaporozhkiy Industrial Institute and the Zaporozhkiy Machine Construction Institute ("The Use of Rare Earth Metals for Inoculation of Cast Irons and Steels for the Purpose of Improving Their Qualities"), the Chelyabinsk Electrometallurgy Combine ("Development of a Technology of Production of Ferro-alloys from Rare Earth Metals in Industrial Vacuum Ovens"), VNIIKhT /expansion unknown/ ("The Use of an Induction Furnace with a Cold Crucible for Producing Homogeneous Alloys from Components with Large Differences in Physical Properties").

Seminar participants showed great interest in addresses (by V.P. Shulika, V.V. Orlov, Ye.L. Fenokhin and others) concerning the introduction of means and methods of intensification of processes in hydrometallurgy and pyrometallurgy, including optimized technical decisions of the creation of ore warehouses, crushing shops, modern refinement apparatus, "Kaskad" type mills, SNK, PIK, IPK and USI /expansions unknown/ type structures of a parametric series of apparatus for leaching, sorption and desorption.

It was noted at the seminar that significant work is continuing in calculating the limiting maximal permissible emission of harmful substances into the atmosphere, the rendering harmless and utilization of gas and liquid emissions, the optimization of methods of determining toxic substances in the atmosphere, the creation of new methods of analytical control for determining tantalum, niobium, individual rare earth elements, low concentrations of rare and trace elements in mineral raw material, extrahents in mineral fertilizers, in waste waters and also for the development of optimization of diagrams of control of technological processes (addresses by Yu.K. Kvaratskhela, N.N. Tokareva and others).

Recommendations of the seminar participants reflect the suggestions for improvement of technology of processing ores, rare, trace and radioactive elements.

2791
CSO: 1870

PUBLICATIONS

DEVELOPMENT OF MATERIALS SCIENCE IN UKRAINIAN SSR ACADEMY OF SCIENCES

Moscow VESTNIK AKADEMII NAUK SSR in Russian No 10 1978 pp 47-54

[Article describing paper by B. Ye. Paton: "On Development of Materials Science in the Ukrainian SSR Academy of Sciences"]

[Text] Academician B. Ye. Paton noted that in his paper that he would discuss only those principal areas of materials-science investigation the results of which have found practical application. The speaker noted that as early as the first five-year plans schools of solid-state physics, physical metallurgy and welding -- in Khar'kov, Dnepropetrovsk, and Kiev -- began to form in the Ukrainian SSR simultaneously with the development of fuel power engineering and metallurgy. World-famous scientific schools in the area of welding and specialized electrometallurgy are successfully operating today in the Ukrainian SSR Academy of Sciences, and investigations are being conducted on various problems of applied materials science, solid-state physics and chemistry, and particularly on new methods of obtaining and processing metallic materials in the solid, liquid and gaseous states; new materials have been created, including on the basis of high-molecular compounds.

B. Ye. Paton further discussed the most important results of research conducted.

Refining of metals and alloys. We know that it is not possible fully to utilize all the useful properties of the crystal lattice of metallic materials, due to harmful impurities and defects introduced into the lattice at various stages of production and processing of materials. Obviously one of the principal ways to improve the properties of metallic materials is to refine them and improve their crystal structure.

Specialists in the field of welding were among the first to seek to obtain initially "pure" steel and subsequently certain other metallic materials as well. In the 1950's they laid the foundations of a new branch of metallurgical production -- special electrometallurgy. And this is understandable: in fusion welding the molten metal vigorously interacts with the refining medium, and particularly favorable conditions are created both for refining the melt and for improving its crystalline structure. Therefore the metal of a weld seam, even without any machining (that is, in cast form), is significantly superior in physicochemical properties to metal of similar composition obtained by conventional metallurgical methods.

One should not forget, however, that welding technology is a micrometallurgical process. Reconstruction of the conditions of melting, refining and forced crystallization, characteristic of the welding process, is by no means a simple matter on the scale of today's metallurgical production. There can be no mechanical transfer of given physicochemical and technological parameters from one area to another. Long years of joint creative efforts on the part of scientists and production specialists were required before special electrometallurgy was created.

Electroslag remelting became most widespread, at first in our country and later abroad as well. The developers of electroslag remelting were awarded the Lenin Prize. Specialized shops equipped with dozens of electroslag furnaces are today producing steels and alloys of hundreds of grades, of practically all structural classes and groups. In addition to merchant ingots of various section, they are producing sheet ingots, slabs, tube billets and pipes.

Especially pure metals and alloys can be obtained by the electron-beam remelting method. With this method a vacuum serves as the refining medium, and a beam of accelerated electrons as the heating source. As a result of investigation of the physicochemical processes of refining in a high vacuum and development of powerful electron-beam guns and other essential equipment at the Electric Welding Institute, in 1964 the country's first shop for the production of especially pure niobium and tantalum was established. In subsequent years process technology was elaborated and production initiated on especially pure high-strength, heat-resisting and precision alloys.

The arsenal of methods in special electrometallurgy also includes plasma-arc remelting, developed at the Electric Welding Institute. Melting with this method is performed with the aid of a plasma arc, while refining takes place as a result of interaction between the molten metal and a special gaseous medium.

In conformity with the resolutions of the 25th CPSU Congress, rapid growth of electrometallurgy is planned, including special electrometallurgy, which is called upon fully to supply all new branches of technology with the highest-quality metal.

Microalloying and modification of steels and pig iron. With all the unquestioned merits of electroslag, electron-beam and plasma-arc remelting, these methods, adding one more conversion to the process of metallurgical production, make the metal more expensive. Therefore it is advisable to refine-remelt only relatively costly steels and special-purpose alloys.

The question arises of what should be done with general-purpose metal, for its quality also must be constantly improved in order to improve the operating characteristics of various machines and devices. Extensive prospects in this area are opened up by the technology of introducing microadditives to the molten metal, which improve the crystalline structure and physical-mechanical properties of the ingot.

Work in this area is being performed at the Ukrainian SSR Academy of Sciences Institute of Problems of Casting. At this institute they have studied many of the laws and patterns of modification and microalloying, have advanced hypotheses on the physical mechanisms of action of small quantities of addition agents and have determined compositions of combined modifiers which make it possible to raise the degree of assimilation of the various alloying elements, to reduce content of oxygen and nonmetallic inclusions, and to improve the mechanical properties of metallic materials.

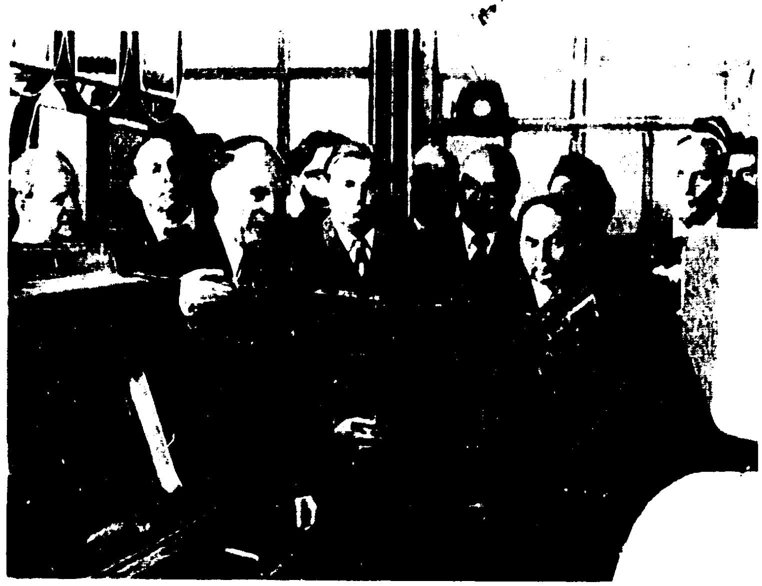
This same institute has developed a new method of modifying steel in the process of pouring, with slag-forming mixtures and granules, which include combined modifying additions based on rare-earth metals. The circulation, convection and gravitational flows in the solidifying ingot ensure uniform distribution of modifying additions throughout the entire ingot and raise the degree of assimilation of basic elements (rare-earth, for example) to 80-90%, which is 50 to 100% greater than indices achieved by the conventional process of modifying in the ladle.

Employment of developed compositions of modifiers and various methods of their introduction into the metal makes it possible to reduce the chemical and physical inhomogeneity of ingots, to reduce by 33-60% the content of oxygen and other nonmetallic inclusions, to increase the density and degree of dispersion of the crystalline structure, and to alter the form of the remaining inclusions in the desired direction.

Modification increases toughness and decreases anisotropy of properties by approximately 40-70%. Replacement of ordinary with modified steel reduces the rolled stock requirements of the economy by 15-20%. We can evidently state that up to 75-80% of the carbon and low-alloy steel produced in this country should now be subjected to modification. The technology of producing combined modifying agents has been mastered by industry, and their centralized production is being set up at a number of ferroalloy plants.

In the last 15-20 years the oldest and most widespread structural material in machine building — cast iron — has been experiencing a rebirth. By means of inoculation metallurgists have succeeded in altering the form of graphite in cast iron -- obtaining spheroidal in place of flake graphite. This has radically improved the metal's physicomechanical properties: it has become possible to produce cast iron with a strength of 100-150 kg/mm^2 and more in place of 15-20 kg/mm^2, and to increase its plasticity 15-20-fold. A new relatively cheap structural material has been obtained — high-strength cast iron, which is equal in properties to carbon alloy steel.

Thus modification of steel and cast iron makes it possible substantially to improve the quality of these most widespread structural materials.



Academician B. Ye. Paton briefs participants in the 35th Session of the Coordination Council on research projects at the Electric Welding Institute imeni Ye. O. Paton of the Ukrainian SSR Academy of Sciences

Synthesis of superhard materials at high pressures. High pressures open up unique opportunities to study physical and chemical phenomena in solids and for synthesis of new materials. The Institute of Superhard Materials of the Ukrainian SSR Academy of Sciences is working particularly vigorously in this area of materials science. In recent years the institute has studied the processes of formation and growth of diamcnd crystals and cubic boron nitride.

Staff members at the Institute of Superhard Materials, the Institute of Problems of Materials Science and the Electric Welding Institute imeni Ye. O. Paton of the Ukrainian SSR Academy of Sciences, jointly with scientists at the Institute of Hydrodynamics of the Siberian Department of the USSR Academy of Sciences, have also achieved diamond synthesis at high dynamic pressures and direct restructuring of the graphite crystal lattice without its dissolving and subsequent recrystallization in a reaction medium. The density of dislocation in these diamonds is three to four orders of magnitude higher than in crystals obtained in high-pressure chambers, that is, with explosive synthesis a plastically-deformed diamond is formed. It was discovere' that diamond generation with this method of synthesis depends on the location of the graphite particles relative to the direction of the shock wave.

A technological process of synthesis of higher-strength cubic boron nitride in increased-volume high-pressure chambers has been developed on the basis of a detailed study of the mechanisms of transition of hexagonal to cubic boron nitride and back, and has been put into production.

High pressures are also employed at the Ukrainian SSR Academy of Sciences Institute of Superhard Materials in producing polycrystalline materials of powders of covalent substances. Polycrystalline materials with excellent cutting properties have been created on the basis of diamonds.

Further investigation of the mechanical and thermophysical properties of polycrystalline diamonds has indicated that their utilization is promising not only as a cutting tool but also as heat dissipators for active electronic components, since within the working temperature interval of microelectronic devices the heat conductivity of diamond is five times that of copper.

Refractory metals and alloys. The most promising as a possible basis of heat-resisting alloys are refractory metals with a body-centered lattice: chromium, niobium, molybdenum, and tungsten. Extensive employment of alloys based on these metals, however, is limited by the tendency of such alloys toward brittle failure at low temperatures and their poor high-temperature corrosion resistance. The physical nature of the cold shortness of refractory metals and alloys based on these metals has been studied at the Institute of Physics of Metals, the Institute of Problems of Strength, and at the Institute of Problems of Materials Science, and this has made it possible to develop methods of increasing their heat resistance and low-temperature plasticity. These methods include the forming of fine-grain and cellular dislocation structure and a certain crystallographic texture of the material, microalloying and alloying with large additions of replacement and injection elements, creation of dispersion-hardened materials and utilization of processes of eutectic crystallization.

A theory of breakdown of polycrystalline material has been elaborated, which takes into account differences in properties of the grain and its boundary. Removal of injection impurities from grain boundaries during microalloying of molybdenum with lanthanum and nickel made it possible to lower the threshold of embrittlement of cast metal and metal in the seam of welded joints to 100°C. Development of highly-efficient methods of refining chromium made it possible to obtain for the first time in world metallurgical practice single chromium crystals retaining plasticity at the temperature of liquid nitrogen. Polycrystalline chromium alloys subjected to refining remelts retain plasticity at temperatures down to -150°C.

Composite materials. Commercial alloys are no longer capable of meeting all the complex and diversified requirements of modern machine building, shipbuilding, nuclear power engineering, and aerospace hardware. One can obtain the requisite properties only by combining different materials, that is, creating composite materials. With composite materials one can specify in advance strength, rigidity, heat conductivity, electrical conductivity, thermal expansion, nuclear properties, erosion resistance, heat resistance, etc, boosting the values of these parameters to a level unattainable in materials of another type.

The simplest type of composite material is composite metals, such as carbon or low-alloy steel clad with stainless or acid-resistant steel. With the traditional process composite materials are obtained by the combined rolling of stacks, by pouring inserta in ingot molds or by rolling built-up stock. The advantages and drawbacks of these technologies are well known. Further progress in development of methods of producing bimetals has been achieved at the Electric Welding Institute imeni Ye. O. Paton. The institute has developed totally new, unique methods of obtaining bimetals and trimetals with the aid of autovacuum pressure welding, electroslag and electron-beam deposition.

Fibrous and dispersion-strengthened materials are in a more complex class of composite materials. Development of such materials requires solving a number of highly-complex technological problems. It is essential to obtain high-strength, high-modulus fibers and particles with specified physical properties, to place them in the matrix with varying orientation, to pack, and to predetermine degradation under mechanical, thermal and other stresses. Research in this area is concentrated at the Ukrainian SSR Academy of Sciences Institute of Problems in Materials Science -- the country's principal organization in the field of powder metallurgy.

Metallic composite materials have now been developed which are based on magnesium, aluminum, copper, beryllium, titanium, cobalt, niobium, molybdenum, tungsten, as well as based on alloys and compounds of these metals with the introduction of metallic and nonmetallic fibers and particles. Such important indicators as tensile strength, modulus of elasticity, heat resistance, and resistance to thermal shock have been increased by two to threefold, and in many cases as much as 10-12-fold in comparison with traditional alloys based on the same metals. Alloys with specified physical properties have also been developed -- heat conductivity, electrical conductivity, magnetic characteristics, resistance to erosion, refractoriness, etc.

Casting, extrusion and pressing. The institutes of the Ukrainian SSR Academy of Sciences have obtained certain results in the area of casting and deformation under high hydrostatic pressur

In the process of casting the molten metal interacts with the ambient air during movement from the melting unit to the casting mold, oxidizing, nitriding, and becoming saturated with hydrogen. Therefore as a rule an effort is made either to shield the metal in the process of its transfer in the atmosphere or to place the entire melting-casting unit in a chamber with a controlled atmosphere or even in a vacuum. Electromagnetic transfer of molten metal has proven more advantageous, however. The Ukrainian SSR Academy of Sciences Institute of Problems of Casting has developed a new family of electromagnetic pumps for effecting such transfer, which have made it possible totally to isolate the transferring metal from the atmosphere.

Another way to effect no-oxidation transfer of molten metal, which makes it possible simultaneously to improve the quality of the castings, is controlled low-pressure casting. With this method of casting the melt is fed from a ladle contained in a sealed chamber, forced under excessive gas pressure, through a metal transfer channel into the casting mold cavity. The rate of solidification of the melt increases by 20-30%, density of the castings increases, and their stress-strain properties improve.

Also extremely promising are developments achieved at the Institute of Problems of Casting connected with active influence on forming of the structure of castings by introducing into the melt dispersed particles of nitrides and carbides of titanium and zirconium. It has been established, for example, that treatment of heat-resisting foundry alloys with dispersed particles increases heat resistance, creep resistance, thermal fatigue and fatigue strength, and toughness across a broad range of temperatures. There is an appreciable increase in the durability of castings treated with dispersed particles.

In recent years a new casting process has been developed on the basis of electroslag remelting at the Electric Welding Institute imeni Ye. O. Paton -- electroslag casting (EShL). It consists essentially in the following: a shaped casting is obtained from metal which has undergone electroslag refining as a preliminary process. The simplest variant of this process, which is sufficiently effective, is melting of the metal directly within a metal air-cooled mold. This process is now being employed in this country to make gate valve bodies for thermal and nuclear electric power stations, crankshafts, pressure vessels together with flanges and inlet-outlet connections, large pinions and other parts.

The most important advantage of EShL is an extremely high coefficient of metal utilization, close to 1. The fact is that with EShL a taphole system is not required, and the head of the casting is just as dense as the bottom portion. As regards properties of the metal, an EShL casting is the equal of a forging or drop forging. The need for more rapid development of EShL in coming years was noted at the 25th CPSU Congress.

Hydroextrusion -- extrusion by means of a liquid -- is a commercial method of deforming materials under conditions of high hydrostatic pressure. This method makes it possible to obtain high mechanical forces and it also possesses important technological advantages: it ensures a high quality of surfacing, the absence of press residue and scale, elimination or reduction of machine-tool operations, etc.

The Donetsk Physico-Technical Institute of the Ukrainian SSR Academy of Sciences has elaborated the physical principles of metalworking processes and control of properties of materials, and has proposed a new process for pressure-working metals -- nonstationary hydroextrusion.

Different variants of industrial processes and methods of processing structural and tool materials have been developed on the basis of scientific research. Record-setting performance characteristics have been obtained for austenitic steels in a nonmagnetic state (ultimate strength was doubled), while retaining plasticity. Methods of reducing the temper brittleness of steel have been developed, and possibilities of plastification of cast brittle bodies and replacement of alloy steels with less short-supply steels have been demonstrated. Hydroextrusion has made it possible to machine composite materials, to eliminate porosity in and increase strength of these materials.

Welding. B. Ye. Paton stated that all steels and alloys are designated chiefly for fabricating welded structures. Therefore welding specialists participate directly in the development of metal materials, while advances in materials science require the development of welding technology, and particularly expansion of the technological capabilities of welding processes.

Specialists at the Electric Welding Institute imeni Ye. O. Paton have developed a number of highly-efficient welding processes which have earned widespread recognition both in this country and abroad. They include electroslag welding, which has made it possible to join parts with a weld-seam cross section of up to 10 m^2 and which has become the basis for development of a large number of new manufacturing processes in metallurgy, welding in carbon dioxide, friction welding, explosive welding, pulse-arc and diffusion welding, underwater arc welding methods, high-frequency welding utilizing the proximity effect, etc. Many traditional welding processes have been given new life thanks to technical improvements.

There has been successful development in recent years of plasma and micro-plasma welding and cutting, ultrasonic welding, various pressure contact welding techniques, including flashing-off butt welding. Electron-beam welding occupies a special place. A sharply-focused electron beam, ranging from tens of watts to 100 kilowatts or more in power, is a versatile tool suitable both for performing the finest precision operations and for joining thick-walled workpieces.

Important results have been achieved in the area of automation of welding processes, results which create the preconditions for welding production to transition to a new and higher technical level.

Protective coatings. Protective coatings improve working efficiency and extend the life of metal materials and reliability of machinery, equipment and instruments. Their utilization makes it possible to reduce irretrievable losses of metals and alloys.

In the last 10-12 years there has arisen the need to protect the surface of high alloys of iron, nickel and titanium, which are widely utilized in power engineering and chemical machine building. Due to a lack of reliable high-temperature protective coatings in the world aerospace industry, refractory metals and alloys based on refractory metals have not come into widespread use up to the present time.

A coating should not only possess a certain combination of properties which enable it to withstand the effect of aggressive environments: corrosion, oxidation, wear, erosion, overheating, etc -- but should also be compatible with the protected surface in such parameters as thermal expansion coefficient, modulus of elasticity, etc. Compositions of protective coatings and methods of applying them to surfaces are being developed at the Electric Welding Institute imeni Ye. O. Paton, at the Institute of Problems of Materials Science, and at the L'vov Physico-Mechanical Institute.

Heat-resistant coatings of complex composition have been developed for operation at temperatures of 900-1200°C, which are capable of forming a dense, high-adhesion oxide film. Electron-beam equipment and a process of applying multiple-component coatings to gas turbine blades have been developed. This process makes it possible to build versatile continuous-operation units applying protective coatings to moving strip and wire. The first continuous-action industrial unit was built in 1975 and is being successfully utilized today.

Composite coverings of metallic and nonmetallic materials, particularly of the laminated type, possess excellent protective properties. Particularly promising are composite coverings which are capable to a certain degree of "self-adjustment," for example, capable of closing up cracks which occur in operation, or capable of "sweating out" and evaporating certain coating components when the surface overheats. These coverings or coatings consist of a porous metallic or ceramic frame and a metallic filler, which at certain boundary temperatures transitions to a liquid state.

Considerable success has been achieved in obtaining coatings with the aid of plasma and detonation methods of metal spray coating.

Metal, cermet and ceramic coatings formed on the surfaces of various items with the aid of the above-described methods are common in shipbuilding, the aircraft, automotive, and chemical industry.

Investigation of the durability and work capacity of materials and structures. The Physico-Mechanical Institute and the Institute of Problems of Strength are doing considerable work on study and prediction of the efficiency of metal materials under conditions of various loads in various environments.

In the course of basic research scientists have elucidated the influence of the features of the operating environment on the physical and mechanical properties of structural materials. Criteria have been developed which make it possible to predict the brittle failure of materials, and principles have been formulated for increasing the useful life of machine parts and structural components utilized under conditions of simultaneous effect of force factors, aggressive working media, radiation, high or low temperatures. Unique testing installations and test beds for testing structure specimens and assemblies have been built.

Standards have been determined on the basis of these studies for calculating the strength of a number of items, such as propeller shafts, marine ship hulls, drill string components subjected to the action of drilling mud and aggressive subsoil water, and high-pressure vessels coming into contact with aggressive media and condensate.

A large number of research projects have been conducted for the needs of nuclear power engineering. Scientists have studied, in particular, the physical and mechanical properties of refractory metals and alloys based on refractory metals as applied to the operating conditions of various reactors and generators.

New methods have also been developed for increasing the resistance of machine and equipment parts as well as structural components to corrosion damage and mechanical failure (special machining, ultrasonic machining, friction-hardening treatment).

B. Ye. Paton noted in conclusion that the Ukrainian SSR Academy of Sciences is planning in the near future to expand in its scientific establishments work on problems of materials sciences, strengthening the facilities of materials science institutes, establishing new laboratories and scientific research areas.

In particular, there will be further development of research on solid-state physics and chemistry aimed at developing new materials with special physical properties: semiconductors, superconductors, radiation and corrosion resistant materials.

B. Ye. Paton emphasized that in order to achieve successful development of all these areas of research it is necessary to examine the question of setting up in Kiev under the auspices of the Ukrainian SSR Academy of Sciences an interministerial (interrepublic) metallic materials center, assigning it the task of coordinating all materials-science investigations being conducted in the establishments of the USSR Academy of Sciences and the academies of sciences of the union republics, as well as work on practical adoption of completed research.

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PUBLICATIONS

TECTONICS OF THE FOUNDATION OF THE EAST EUROPEAN AND SIBERIAN PLATFORMS

Moscow TRUDY GEOLOGICHESKIY INSTITUT (Works of the Geological Institute): TEKTONIKA FUNDAMENTA VOSTOCHNO-YEVROPEYSKOY I SIBIRSKOY PLATFORM in Russian No 321, 1978 signed to press 14 Dec 77 pp 3-10, 209-210

[Introduction, annotation and table of contents from book edited by M. S. Markov, Izdatel'stvo "Nauka", 211 pages, 850 copies]

[Text] General aspects of early Precambrian tectonics are examined in the book. Structures and features of the formation of the Precambrian foundation of the East European and Siberian platforms, characterized on the basis of the conception of the stage by stage formation of the earth's continental crust as the result of metamorphosis of the ocean crust of the geologic past, are described. The importance of horizontal movements in the formation both of the continental crust and of structure is emphasized. New scenarios regarding the structure and tectonic zoning of the foundation of the East European and Siberian platforms are offered and the stages and phases of the development of their continental crust are presented. The text is accompanied by 4 tables, 42 illustrations and 443 bibliographic references.

Introduction

Precambrian rocks, as is well known, comprise most of the earth's consolidated crust within the continents. Areas made up primarily of sedimentary and magmatic rocks of the foundation of the ancient platforms alone constitute four-fifths of the continental area of the earth. The period of genesis of Precambrian crust covers an enormous span of time, at least 7 times longer than the Phanerozoic. Nevertheless, general theories of the development of geological processes in all fields of earth sciences have been developed and continue to be developed primarily on the basis of analysis of the Phanerozoic history of our planet. The appearance in recent decades of new methods of investigations and more detailed analysis of the regional geology of the Precambrian and publication of various thematic works on these most ancient formations have greatly expanded the prospects for understanding the ancient stages of the formation of the continental crust. Investigations of this problem and the solution of various problems of the development of geologic phenomena during the formation of the earth's crust in time and space since the earliest stages of the formation of its mantle certainly will provide a key not only to a better understanding of the general theory of the formation of the earth's crust, but also to a knowledge of the principles of localization of mineral resources, which are so numerous and diversified in Precambrian rocks.

The most important aspects of the tectonics of the ancient formations of our planet are those pertaining to the formation of various mantles of the earth's crust and the question of the genesis and development of Precambrian structures, which is closely related to it. The views held by researchers engaged in the analysis of these questions diverge very strongly at the present time.

There is an independent scientific trend, according to which the geologic development of the earth in the Archean, with a top geochronological boundary of 2500-2700 million years, differed so strongly from its more recent development that tectonic processes have no continuity on that boundary. The advocates of this belief feel that the so-called nuclear stage of development, during which domes and dome-like tectonic structures, with the complete absence of linear structures, formed on an extremely ancient basitic basement, corresponds to the earliest stages of the formation of the earth's crust. The genesis of the nuclear mantle within the continents culminated in the formation of a granitic-metamorphic stratum. It is specifically on that stratum, starting at the Lower Proterozoic, that geosynclinal systems, similar to analogous systems of the Phanerozoic, began to develop in some cases, and protoplatform mantles, which either ultimately survived to our time, or which even participated in subsequent geosynclinal development, developed in other cases.

In opposition to the nuclear conception stand the no less widely held and traditional views on which G. Shtill's hypotheses are based. These hypotheses state that the earth's crust and its structures formed in those ancient times in the same direction as the Phanerozoic, and the geosynclinal process occurred universally on the continental crust.

Both of the described conceptions contain elements of fixism. They are based on the concepts of the pre-eminence of vertical tectonic movements, which govern the formation both of different mantles of the earth's crust and of structural forms inherent to them. Only a comparatively few horizontal displacements of rocks, leading to the appearance of small-amplitude upthrusts and, in exceptional cases, to mantles just as small in amplitude, are admitted. The role of large lateral displacements of large plates and blocks in the formation of early Precambrian structures is denied, and it is assumed that the crust and its structural forms evolved in a position fixed for all time.

To these concepts is closely related the hypothesis of the basification of the earth's crust in a form such that the continental crust evolves into the oceanic crust as a result of physicochemical metamorphosis. The hypothesis of basification at first explained the formation of the modern oceans in the Mesozoic, but then it began to be applied to early Precambrian structures in cases when they are characterized by a thin granito-metamorphic layer, or when such a layer does not exist at all.

Individual researchers have tried in recent years to explain the formation of the Precambrian crust and its structures from the standpoint of the new global tectonics. Just as for the Phanerozoic, they identified lithospheric plates and zones of moderately sized oceanic ridges, presumed to have existed in the Precambrian, from which movements of these plates, due to spreading, resulted in subduction and obduction. However, these interpretations are so hypothetical for the early Precambrian that they have not gained much recognition. Aside from them, however, no analysis of the structures and conditions of the formation of the crust for the Archean and Proterozoic has ever been undertaken in the light of the scientific concept of mobilism. Large lateral displacements of lithospheric plates and blocks, accompanied by crustal formation processes, have not been discovered or described, just as phenomena of the destruction of the crust, which evidently occurred in the deep Precambrian, and which were caused by the formation of new specific tectonic forms, have not been discovered or described.

The present status of tectonic research on Precambrian formations bears testimony to the fact that many fundamental aspects of the structure of the crust at the beginning of the geologic development of our planet still have not been investigated sufficiently. This behooves researchers to concentrate their attention on studies aimed at explaining the basic laws of the conditions of the formation of the crust and the development of structures of various tectonic categories, inherent to it.

Analysis of Precambrian tectonics understandably has always been based on progress in this field of geologic disciplines for the Phanerozoic. A new scientific trend emerged recently, related to the discovery of the fact that the foundation of the earth's crust was the oceanic crust of the geologic past, and that geosynclinal development is a process of the formation and redistribution in space and time of the granitic-gneiss mantle, which ultimately culminated in the development of the continental earth's crust. Ophiolites, the bottom member of which is the so-called malanocratic basement, made up of ultrabasites, gabbroids and amphibolites, which alternate everywhere in the stratigraphic series, belong, as is known, to the type of ocean crust that appears in Phanerozoic folded formations. Graywacke, flysch and andesite formations, and plagiogranitization processes and the formation of diorites and plagiogranites, are especially characteristic of the transition stage of geosynclinal development. And, finally, molasses, volcano-plutonic complexes, potassic metasomatosis and the formation of potassic granite massives typify the orogenic stage, which concluded the geosynclinal process.

Nearly all researchers, engaged in the analysis of the structure of the early Precambrian crust, identify large blocks, among which adjacent blocks are characterized by different ages of complexes of rocks inherent to them, different compositions and different degrees of metamorphism. In these blocks attention should be focused on the order of formation of the different complexes of rocks, their differences from the Phanerozoic complexes and the possibility that they belong to the three above-mentioned stages of formation of the crust. This approach to the analysis of the structural principles of the early Precambrian crust has been used by certain geologists, not without success. Nevertheless, there remain many unresolved questions, pertaining to various aspects of the similarity and difference of cross sections of the Phanerozoic and Precambrian crust.

All subdivisions of the ophiolitic association, characteristic of folded structures of the Phanerozoic, are also known to exist in folded structures of the Precambrian of any age. However, the structural localization and position among melanocratic foundation rocks of sometimes large bodies of anorthosites, which are found extensively in the Precambrian, but are virtually nonexistent in Phanerozoic formations, remain mysteries. Nor is there any reliable information about the stratigraphic position and relationships with analogs of the melanocratic foundation of early Precambrian crystalline schists of different composition, in which some of the principal rock-producing minerals are pyroxenes, and sometimes olivine. The same can be said of various eclogites and other ultrabasic and basic rocks. There is hardly any doubt that the often strongly metamorphized basic vulcanites and jaspilites, associated with their strata, are the Precambrian counterparts of the upper members of the ocean crust of the Phanerozoic.

In the deep Precambrian cross sections various crystalline schists and paragneisses evidently were deposited over formations of ocean type crust. These metamorphized series include a series of unusual strata, for which it is hard to find metamorphized counterparts among Phanerozoic sediments. Among these strata, for example, are various high-alumina crystalline schists -- disthenic, cordieritic, sillimanitic, staurolitic, etc. They probably are the result of the metamorphosis of a special type of terrigenic sediments and volcanogenic formations with a sharply higher concentration of aluminum oxide, which did not form later during the formation of the Phanerozoic crust. With strata of high-alumina crystalline schists also are often associated metamorphized vulcanites, the primary composition of which corresponds to andesitic basalts, andesites and more acidic varieties. These vulcanites probably do not differ fundamentally from similar volcanogenic formations of the Phanerozoic. There is reason to believe that all these terrigenous and volcanogenic formations correspond to the transitional stage of the formation of the Precambrian earth's crust.

Of special importance is the position of strata similar to flysch and molasses in cross sections of the early Precambrian. These strata evidently do not exist in the Archean, and the conditions of the gensis of the oldest sections of the granitic metamorphic layer of the continental crust differed substantially from the conditions that existed afterward, in both the Precambrian and Phanerozoic.

Thus, by applying to folded formations of the Precambrian the same method of analyzing the stage by stage development of the earth's crust as is applied to folded formations of the Phanerozoic, it is possible to explain the basic principles of its evolution in time and space.

The modern structure of early Precambrian formations is extremely complex. It has long been known that early Precambrian ophiolites in most cases are deposited in the form of linear bands, which separate the above-mentioned higher large blocks. Soviet scientists showed recently that these bands are characterized by an imbricate structure, caused by numerous upthrusts, which, in combination, produced monoclinal tectonic forms. These monoclines occurred before the main granitization phase, which covers them and is especially extensive in adjacent blocks, in which the basic fields of various granitoids are concentrated. These new findings refute the idea that ophiolite bands formed on a gneiss bed in the form of linear narrow troughs, which in the structure of the modern shields comprise a kind of synclinoria with well developed limbs. There is hardly any doubt that the cross sections of the ocean crust that once (before folding processes and as a result of the crowding together of rocks) participated in the formation of the modern structure of imbricate monoclines, filled vast spaces between sections, made up of more mature crust, i.e., of crust of the transitional type, and in some cases of the continental type. The features of the primary association and of subsequent structural transformations of such spaces with these sections deserve careful analysis.

Granitic gneiss domes in the deep Precambrian belong to a special category of structures. The fact that they are dome shaped is confirmed not only by direct observations in the field, but also by aerial photographs and satellite photographs. The internal structure of the domes is exceedingly complex. Many researchers emphasize that the axial planes of the numerous plastic folds of rocks, inherent to them, often slope from the periphery of the dome toward its apical part. The domes are run through by autochthonous and allochthonous granitoids of different composition and origin to their very leucocratic varieties of potassic specialization. Manifestations of granitization and migmatization are just as common. The domes sometimes occupy large areas, are close together and in plan resemble unique "flocks" or "swarms" of oval tectonic forms. The parts between the domes are usually also made up of gneisses with a very complex plicative and disjunctive structure. Amphibolite seams and members are often encountered in the bottom part of the gneiss domes. The fact that the plagiogneisses of the domes were deposited on various volcanic and sedimentary sediments is well documented and is confirmed by outcroppings in which these rocks retain their relict textures.

All researchers who have investigated the gneiss domes conclude that they underwent a long period of hereditary development, and it is not hard to agree with this conclusion. They undoubtedly formed in the Archean and early Proterozoic on a basitic substratum. Gneiss domes are also known to exist in rocks of the Riphean and Paleozoic, and even of the Mesozoic. It is obvious, nevertheless, that as geologic time passed gneiss domes occurred less and less frequently, and the period of time during which they were formed steadily decreased. However, many aspects of the mechanism of the formation of gneiss domes and the causes of their independent development among neighboring and contemporary linear structures remain uncertain. These questions obviously are deserving of investigation and resolution.

An analysis of geologic maps, in different scales, of individual regions of the Baltic shield and of other ancient platforms leaves no doubt that in the deep Precambrian (Archean and early Proterozoic) there occurred beds just as large as bed structures of the Phanerozoic in terms of the amplitude of their horizontal displacement, and quite probably even larger. Of exceptional importance is the fact that rocks of the ocean crust in Phanerozoic bed structures often lie on the continental crust, just as individual subdivisions of the ophiolitic association in bed structures of the early Precambrian probably lie on plagiogneisses and crystalline schists associated with them. These ancient beds evidently sometimes retained their initially level sedimentation in the form of variously sized tectonic residual outcroppings and rather large individual plates. These allochthonous structures obviously were repeatedly dislocated in places into flat syn- and antiforms and underwent metamorphism.

All these questions about the ancient bed structures of the earth require proper analysis and the gathering of facts that conclusively confirm them. It must also be said in this connection that individual researchers, engaged in the geology of the early Precambrian, view large residues of these beds, made up of ultrabasites at the bottom and of a banded complex of gabbroids of the melanocratic foundation at the top, as stratified intrusions into the gneiss basement and compare them with the well known stratified alkaline intrusions of ultrabasic and basic composition, which occurred during the formation of the mantles of the ancient platforms. Judging by geophysical data, however, these are crust-free intrusions, which confirms the fact that they belong to bed structures. Many fields of granitic-gneissic domes in the modern structure of the early Precambrian obviously also occupy an allochthonous position; they were autochthonous tectonic forms only during the time of their formation.

Beds and upthrusts lead to the formation of destructive structures of the earth's crust, since extention inevitably occurs in their wake, followed by disintegration of crustal mantles and, eventually, by the formation of sections from which other members of these mantles are separated. Destructive (riftogenic) structures of a different kind have also been identified in recent years in Phanerozoic geosynclinal systems. These structures occurred as a result of unilateral or bilateral displacement of the previously formed granitic-gneissic metamorphic mantle and of the completely mature continental crust. Indications of these structures are facies of a special type, represented by various coarsely fractured rocks (conglomerates, gravelites, sedimentary breccia and sand), alkaline vulcanites and ultrabasic alkaline intrusions. These systems are also now being found in early Precambrian formations. However, methods of recognizing destructive structures of this kind still are not well developed. During the development of methods of identifying these structures it is important also to determine what role they played in the overall process of structure formation in the early Precambrian.

According to geophysical data, on the shields and foundations of the plates of the ancient platforms there are large and small regions of different configuration in plan, which are devoid of a "granitic" stratum of the crust (the Precaspian segment, for example). Three possible cases of their origin are plausible: 1) residues of the primary ocean crust; 2) exposure of the ocean crust to the rear of large bed structures, fragments of which survive to this day; 3) fragments of the ocean crust, which also still exist, but as a result of extensions (destruction of the second kind), which took place in the continental crust. All these cases of the formation and survival of parts of the crust, on which there is no granitic stratum, not only are plausible, but they evidently also reflect reality. The problem is to find structures of this kind, describe them and explain their role in the formation of the continental crust.

The space and time principles of such structural categories, so common in the Phanerozoic, as fringe depressions, fringe volcanic belts with their characteristic volcanoplutonic formations and certain other tectonic forms, have not been explained for the early Precambrian. Exceptional importance is attached to the complete and careful revision of all existing geophysical data and drilling data on the ancient platforms, especially of the East European and Siberian platforms, in the light of the scientific principles on which this work is based.

These principles are the following: 1) recognition for all ages of the Precambrian of the primitiveness of the ocean crust in relation to the continental crust; 2) development of the continental crust during the process of geosynclinal development, both by the formation of new structures and by lateral redistribution of previous parts of the crust; 3) progressive growth of the continental crust in space and in time, but irregular on different parts of the earth's surface; 4) recognition of the important role of horizontal movements in the formation of the structure of mantles of the crust in addition to vertical movements, such that the amplitude of horizontal movements ultimately is many times greater than the limit of vertical displacements; 5) irregular manifestation of these two categories of tectonic displacements; 6) directed periodicity and phasing of the structural development of our planet, affecting it simultaneously, but manifested differently in many of its segments and even hemispheres.

Aspects of the creation and evolution of the continental earth's crust in the early Precambrian are examined and the role of lateral tectonic displacements during the process of its development is demonstrated in this book. The mechanism of the formation of the granitic-metamorphic bed and of the continental crust of the ancient platforms is completely explained by way of analysis of the early Precambrian tectonics of certain structural elements of the foundation of the East European and Siberian platforms. This is the first experience in the extensive application of a new principle of structural analysis, developed during compilation of the tectonic map of Eurasia (Peyve, et al, 1976), to early Precambrian formations.

The first part of the book pertains to analysis of the structure and history of the formation of the continental crust of the Baltic shield and the eastern part of the Russian plate. This portion is analyzed in the section written by N. A. Shtreys, A. S. Novikov, A. A. Savel'yev, G. L. Goroshenko and V. P. Martynova -- "On the Bed Structure of the Baltic Shield," in which an attempt is made to apply to an analysis of the tectonics of the Baltic shield the principle of the stage by stage development of the continental crust of Phanerozoic folded zones, and in which is also proposed a fundamentally new scheme of the structural zoning of the shield, which explains the close relationship between phenomena of granitoidal magmatism and lateral structuring. It is shown by example of an analysis of the Sveco-karelian segment of the Baltic shield that its formation occurred during the process of the progressive buildup of the tranitic-metamorphic layer of the earth's crust, both in space and in time. The stages of development, marked within the mentioned segment of the plate, which occurred at different times -- the oceanic, followed by a stage of transition to the continental ("island arc"), turned out to be next to each other, which undoubtedly was the result of their lateral convergence. Narrow strips of oceanic cross sections of imbricate-upthrust structure often are traced in zones where plates of different ages join together. Some features of the tectonics of the riftogenic structures of the Svecokarelian segment are also described and their space and time relations with the continental crust are analyzed.

The Sveconorwegian province occupies a special position among the tectonic elements of the Baltic shield. Modern data contradict widely held notions of the Archean-Svecofenian age of development of its continental mantle and subsequent regeneration in the Gotskiy (early Riphean) stage. The second part of the monograph: "The Structure and History of the Formation of the Continental Crust of the Sveconorwegian Province of the Baltic Shield," written by A. S. Novikov and Sv. A. Sidorenko, pertains to an examination of these new materials on the geology of southern and central Sweden and of southern Norway and to a generalization of the results of field excursions in Sweden. The authors show that the southwestern fringe of the Baltic shield exhibits all the elements of the formation cross section that are inherent to the continental, transitional and oceanic stages of development of the earth's crust. The examined segment is unique because an abbreviated type of crustal cross section formed there. Much importance is attached to the fact that the strongest manifestations of granitoidal magmatism are linked in time with bed-upthrust structuring, each time preceding granitization and ultrametamorphism. These conclusions, derived on the basis of geohistorical analysis of the structure of the Sveconorwegian province, agree satisfactorily, by and large, with isotopic geochronology data.

The third part, written by K. A. Klitin, "The History of the Formation of the Earth's Crust of Scandinavia in the Riphean Based on Data of Isotopic Geochronology," deals with a generalization of data from numerous determinations of ages of metamorphic and magmatic rocks by the Rb/Sr and U/Pb methods in different laboratories around the world. It is shown that the earth's crust in western Scandinavia was formed over a period of many hundreds of millions of years, embracing the early and middle Riphean. The geochronological boundaries of the formation of metamorphic rocks go back to 1.2 and 1 billion years; the 850-900 million year level of the massive appearance of potassic and normal granites is also identified. Some aspects of the relations between geosynclinal formations and rocks of the melanocratic basement are discussed in the work.

The study of S. V. Bogdanova and R. A. Gafarov "The Composition and Structure of the Foundation of the Eastern Part of the Russian Plate and Some Features of the Formation of the Continental Crust in the Early Precambrian" (Part Four) is the first study of the history of the formation of the continental crust of the foundation of the eastern part of the Russian plate. Major differences in the evolution of endogenous processes in the Archean middle massives and linear late Archean-early Proterozoic folded zones are disclosed on the basis of a thorough analysis of the composition and features of formation complexes and of the petrophysical characteristics and structural relations of early Precambrian formations of the most fractured Volga-Ural region. Early Archean volcanogenic sedimentary strata are found to have played a special role in the development of the Archean massives, and deep upthrusts, which split massives and linear zones, also played an important role. A geological-geophysical zoning of the eastern part of the Russian plate is presented.

The second part of the book "The Tectonics and History of the Formation of the Continental Crust of the Siberian Platform" consists of two sections. The first -- "The Tectonics and Major Stages of the Development of Continental Crust of the Southern Part of the Siberian Platform in the Early Precambrian" -- belongs to A. M. Leytes and V. S. Fedorovskiy. The authors reanalyze the structure and important stages of the formation of the earth's crust of the Aldanian shield. In the continental crust of the Aldanian shield, which formed up until the Riphean, they identify formation complexes and structures of a protometamorphic granulitic basitic layer at the 3.5-3.0 billion year level, the melanocratic basement and sedimentary volcanogenic mantle of which were subjected to granitization and regressive remetamorphism in the early Proterozoic. The complexes and structures of the formation and development of the granitic-metamorphic stratum are represented by zonally metamorphized series of riftogenic troughs, formed by the oceanic, transitional and continental stages. In the complexes of the transitional stage are identified sedimentary volcanogenic "island arc" series, sedimentary strata of the protocontinental basement, slope and shelf and internal depressions of the protocontinent, as well as massives of granitoids of plagiogranitic gneiss and granodiorite-granite formations, and volcanoplutonic series, combined with late molasses, are found in the complexes of the continental stage. The main tectonic irregularities of the early Proterozoic, which comprise a "protocontinent-ocean" system, in southeastern Siberia are identified. A lateral series of structures in that system, including an internal protocontinental trough, protocontinental shelf, slope, foot, island arc and oceanic region, and a lateral series of the corresponding metamorphized primary sedimentary and sedimentary-volcanogenic formations, is identified and analyzed. It is shown that no primordial continental crust of the Phanerozoic type existed in southeast Siberia. The first mature continental crust appeared there only by the beginning of the Riphean, 1.8-1.6 billion years ago. It is explained that its formation occurred during stages analogous to those established by an analysis of the processes of development of the continental crust of geosynclinal folded systems of the Phanerozoic. This provides new opportunities for correlating the processes and complexes of the Precambrian and Phanerozoic, which is essential for the development of a unified theoretical model of the development of the continental crust.

In section two "The Structure of the Foundation of the Siberian Platform and Certain Features of the Development of Its Continental Crust," R. A. Gafarov and Yu. I. Prozorov, on the basis of generalized geological and geophysical materials, present a tectonic zoning of the Siberian platform, which, from the standpoint of mobilism, gives an idea of the stage by stage development of its foundation. Large segments of two types of lithospheres are found. The first type of segments, which have a mature continental crust, are confined to its fringes. The second type of segments, made up primarily of a granulitic-basitic protometamorphic stratum, comprises the central part of the foundation of the Siberian platform.

Major questions of theoretical tectonics, aimed at explaining the general principles of the formation of the continental crust of the ancient platforms in the deep Precambrian, are examined in the monograph in new light. The solution of many such problems would require the analysis of voluminous comparative material on the foundations of the ancient platforms, located outside of our country. Even a cursory examination of the tectonics of these platforms indicates that each of them, and some of them taken together, possess specific and unique structural features. The ancient platforms of Gondwanaland are particularly important. They, as is known, have folded zones of the Riphean, which not only extend along the edges of the platform, but within them as well. There is reason to believe that an analysis of the tectonics of the platforms of Gondwanaland, along with data on the tectonics of the platforms of the Northern Hemisphere, will provide an answer to the question of the principles and periodicity of the development of the continental crust in the earth's entire Precambrian annals.

Table of Contents

Part Two

7872
CSO: 1870

PUBLICATIONS

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PROCEEDINGS OF 6th ALL-UNION SEMINAR ON STATISTICAL HYDROACOUSTICS

Novosibirsk TRUDY SHESTOY VSESOYUZNOY SHKOLY-SEMINARA PO STATISTICHESKOY GIDROAKUSTIKE (Proceedings of the Sixth All-Union School-Seminar on Statistical Hydroacoustics) in Russian 1975 signed to press 20 June 75 pp 2, 388-390, 379-387

[Annotation, table of contents, and bibliographic list from book, N. G. Zagoruyko, V. V. Ol'shevskiy, and S. V. Pasechnyy, editors, Izd-vo In-ta Matematiki SO AN SSSR, 700 copies, 390 pages]

[Text] This volume contains the proceedings of the 6th All-Union Seminar on Statistical Hydroacoustics, organized by the Hydrophysics Council of the Presidium of the USSR Academy of Sciences, the Institute of Mathematics of the Siberian Department of the USSR Academy of Sciences, the Acoustics Institute, Kiev Polytechnic Institute, and the All-Union Scientific Research Institute of Applied Physical and Radio Measurements. The seminar was held at the latter institute in September 1974 in the town of Mendeleyevo, Moskovskaya Oblast. The papers contained in this volume deal with problems of mathematical description of random fields and signals, statistical measurements, problems of modeling, and the results of experimental investigations.

The materials in this volume are of interest to specialists working in the area of hydroacoustics, radio engineering, instrument analysis of random processes and fields, as well as students in these areas of specialization at higher educational institutions.

Contents	Page
Ol'shevskiy, V. V. Modeling in Statistical Hydroacoustics	3
Taradanov, L. Ya. Some Features of Hydrophysical Modeling	25
Kaptyug, A. A., and Ol'shevskiy, V. V. Some Mathematical Aspects of Modeling in Statistical Hydroacoustics With the Aid of a Computer	33
Genis, V. I., Oboznenko, I. L., and Taradanov, L. Ya. Optimization of Conditions of Experimental Investigations in Hydrophysical Modeling	45

List of Papers Published in the Preceding Five Volumes of Proceedings of the All-Union Seminar on Statistical Hydroacoustics (1970-1974)

Proceedings of the First All-Union Seminar on Hydroacoustics. Izdatel'stvo Nauka, Siberian Department of the USSR Academy of Sciences, Novosibirsk, 1970.

Contents

Proceedings of the Second All-Union Seminar on Statistical Hydroacoustics, Nauka, Siberian Department of the USSR Academy of Sciences, Novosibirsk, 19;1

Geranin, V. A. Analysis of Non-Stationary Random Processes 205-220

Geranin, V. A., Goncharova, A. Ya., Mironov, N. A., and Prodeus, A. N. 221-228

Voloshin, G. Ya. Some Problems of Theory of Hierarchic Recognition Systems Applied to Processing of Hydroacoustic Signals 229-246

Makhonin, G. M., Orlichenko, A. N., and Rizhov, V. P. Methods of Measuring Signal/Noise 247-262

Gatkin, N. G. Space-Time Optimal Processing for a Signal With Fluctuating Amplitude 263-270

Lbov, G. S. On Optimization of Functioning of Hydroacoustic Measurement Systems 271-282

Trokhan, A. M. Investigation of the Characteristics of Turbulence by Optical Methods 283-297

Krasnyy, L. G. Detection of Signals Under Conditions of Incomplete A Priori Information on the Correlation Function of Interference 298-304

Reznik, A. M. Some Questions of Measurements in the Problem of Recognizing Sound Images 305-313

Yudenkov, I. P. Characteristics of Clipping Detectors With Correlated Interference 314-324

Proceedings of the Third All-Union Seminar on Statistical Hydroacoustics. Izdatel'stvo VNIIFTRI, Moscow, 1972

Gulin, E. P. On Correlation Characteristics of a Wave Field of a Non-Monochromatic Radiation Source in Media With Random Parameters 4-20

Galanenko, V. B., and Karnovskiy, M. I. Correlation and Directional Properties of Fields of Non-Stationary Inhomogeneous Sources 21-30

Blok, A. V., and Ol'shevskiy, V. V. On the Influence of the Parameters of Radiated Signals on the Frequency and Time Characteristics of Sea Reverberation 31-45

Ol'shevskiy, V. V. Statistical Characteristics of Sea Reverberation With Mutual-Correlation Processing 46-60

Aleshchenko, O. M., and Yudenkov, I. P. On Amplification of a Receiving Antenna Array in a Multiple-Component Interference Field 281-283

Ryzhov, V. P. Application of the Consolidation Method for Processing Signals Under Conditions of Significant A Priori Uncertainty 284-291

Rogozovskiy, O. A. On Constructing Optimal Polyharmonic Signal Detectors With Non-Rayleigh Distribution of Harmonic Amplitudes 292-301

P'yanov, V. M. Interference Resistance of an Optimal Echo Signal Detector in Detection of an Echo Signal 302-309

Kabakov, L. S. The Role of Memory in Multiple-Frame Signal Detection 310-314

Voloshin, G. Ya. One Method of "Multiplying" Hydroacoustic Signal Realizations 314-321

Gershmakh, S. G. Prikhod'ko, V. P., and Svet, V. D. A Statistical Method of Estimating Non-Linear Distortions in Hydroacoustic Systems and Communication Channels 322-327

Votsekhovskaya, S. A. Statistical Characteristics of an Acoustic Field Arising as a Result of the Formation of Ice Cover Fractures 328-337

Polyanskaya, T. V., and Skipa, M. I. Models of Hydroacoustic Signals Formed in the Vicinity of the Sea Floor 337-343

Yemel'yanenko, I. V., Libenson, Ye. B., Paliy, A. F., and Paperno, A. I. Some Results of Experimental Investigations of Sea Reverberation During Radiation of Complex Signals 343-347

Proceedings of the Fourth All-Union Seminar on Statistical Hydroacoustics (SG-4), Izdatel'stvo of the Siberian Department of the USSR Academy of Sciences, Novosibirsk, 1973

Tsvetkov, E. I. Systems Engineering Methods in Statistical Hydroacoustics 3-13

Zayezdnyy, A. M. Classification of Signals Propagated in a Water Medium, Based on Processing Them According to Structural Properties 14-22

Solodovnikov, V. V., and Birgokov, V. F. Optimal Processing of Non-Stationary Random Hydroacoustic Signals 23-32

3024
CSO: 8144/0717

PUBLICATIONS

AUTOMATIC CONTROL SYSTEMS IN SPACE

Moscow TRUDY VII MEZHDUNARODNOGO SIMPOSIUMA IFAK PO AVTOMATICHESKOMU UPRAVLENIYU V PROSTRANSTVE (V CHETYREKH TOMAKH) TOM 1 (Works of the 7th International IFAA Simposium on Automatic Control in Space (in 4 volumes) Volume 1) in Russian 1978

[Table of Contents from book]

[Text] CONTENTS Page

9082
CSO: 8144/0746

PUBLICATIONS

MAGNETIC RECORDING IN DATA TRANSMISSION SYSTEMS

Moscow MAGNITNAYA ZAPIS' V SISTEMAKH PEREDACHI INFORMATSII (Magnetic Recording in Data Transmission Systems) in Russian 1978 signed to press 19 Sep 77 pp 2-4, 303-304

[Annotation, Foreword and Table of Contents from book by Maksim Vladimirovich Gitlits, Izdatel'stvo "Svyaz'", 7,000 copies, 305 pages]

[Text] The book is devoted to problems of using magnetic recording apparatus (AMZ) in data processing and transmission systems. The relationship between the fidelity of various methods of recording and the design parameters of the apparatus is analyzed and relations which determine the requirements on the recording systems are presented.

The book is intended for engineering-technical personnel engaged in development and operation of magnetic recording apparatus and will be useful to students of VUZ's.

Foreword

The vigorous development of science and technology at the modern stage of the scientific-technical revolution, penetration of man into space and into the ocean depths and careful study of the natural resources of our planet lead to creation of large volumes of information, the need to transmit large information flows over communications channels and to present it in a form suitable for perception by man or processing by machine. Special information systems are being developed to receive, transmit and process data, the number of which includes audio and television broadcasting complexes, communications and telemetry systems, the information subsystems of ASU and so on.

The type of transmitted signals varies repeatedly during data transmission over long and especially ultralong distances, communications channels different in capacity require matching and problems of matching the rates of reception, processing and storage of the received information occur. The enumerated problems and many others cannot be fulfilled without storage devices, as which magnetic recording apparatus (AMZ) are used. Modern AMZ are complex devices which include large radio complexes and which provide the capability of their functioning. One can say without exaggeration that such modern trends of science and technology as cosmonautics, computer technology, telemetry and control and scientific instrument building would be impossible without AMZ.

Magnetic recording is being developed at the juncture of many sciences -- electronics, precision mechanics, automatics, physics and chemistry. The complexity of interaction of individual AMZ subassemblies is determined by this on the one hand and the complexity of analyzing the phenomena occurring during the record-playback process is determined on the other hand. This explains the fact that specialists of different profile are involved in development of AMZ, moreover, those who, for example, are engaged in design of the transport mechanism or in development of the recording carriers, due to the inevitable specialization, do not always have a sufficiently clear idea of what requirements the selected method of signal conversion places on the AMZ subassemblies being developed by them. Due to this specialization, the main publications in the field of magnetic recording are devoted to individual aspects of recording theory and technology, while the developers of the apparatus are usually interested in the problem of how variation of the parameters of individual blocks or subassemblies of the AMZ affects the resulting characteristics of the system as a whole, what requirements should be placed on the AMZ subassemblies in order to provide the required metrological characteristics of the apparatus with minimum expenditure of funds and so on.

The users of AMZ are in an even more complicated position. In solving the problem of the applicability of the AMZ in the designed system, they are forced to use the complex of indicators given in the certificates for the AMZ such as amplitude-frequency characteristic, nonlinear distortions, coefficient of velocity fluctuations and dynamic range. However, from the consumers' viewpoint, of greatest interest is analysis of how much the signal is distorted by a given criterion during recording-playback and how these distortions are reflected in the resulting metrological characteristics of the complex as a whole. If one takes into account that even the same apparatus may be "accurate" or "inaccurate" as a function of the type of output signal processing, the causes of many failures and even of the bitter disappointments experienced by specialists who attempted to regard the AMZ as a "black box" and to use haphazardly the taken apparatus in developed data processing and transmission systems, become clear. It is also no accident that AMZ very frequently are the greatest "bottleneck" in large radio complexes and therefore limit their capabilities.

The purpose of this book is to attempt to "build bridges" first between the developers and users of AMZ and second between the developers of individual AMZ subassemblies and those who combine these subassemblies into a unified complex and to show which parameters of the system and in what manner they affect the fidelity of magnetic recording with different methods of message processing.

Systems are analyzed on the example of AMZ used in data transmission and processing systems. However, where it was possible and logical, the author attempted to regard the system in general form without indication of its specific designation.

The outline is constructed so that the reader has no need to refer to other sources with systematic reading of the books to study one or another important problem, although the previously described materials are outlined as compactly as possible.

However, the fact that readers may have questions for which they are unable to find a direct answer in the book is inevitable, since its framework is limited and the topic is very broad. In these cases it is useful to refer to the special literature, a very detailed bibliography of which is presented at the end of the book.

The useful advice, recommendations and friendly support of I. Ye. Goron, V. G. Korol'kov, O. V. Poritskiy, A. I. Viches, Yu. V. Skalin and many other colleagues and comrades at work rendered invaluable assistance to the author during work on the manuscript, to whom the author feels it is pleasant duty to express deep gratitude. A. I. Viches made materials on measurement of the channel characteristics, partially used in the appendix, available to the author. The author is grateful to the scientific editor of the book V. A. Vatsenko and the reviewer N. N. Slepov, whose labor and useful advice contributed to a significant degree to improvement of the contents of the book.

Contents

6521
CSO: 1870

PUBLICATIONS

COMPUTATIONAL METHODS AND PROGRAMMING

Moscow VYCHISLITEL'NYYE METODY I PROGRAMMIROVANIYE XXVI (SBORNIK RABOT NAUCHNO-ISSLEDOVATEL'SKOGO VYCHISLITEL'NOGO TSENTRA MOSKOVSKOGO UNIVERSITETA) (Computational Methods and Programming, 26: Collected Papers by the Scientific-Research Computer Center of Moscow University) in Russian 1977, signed to press 28 Sep 1976, pp 2, 191

/Annotation and table of contents from book edited by V. V. Voyevodin and V. A. Morozov, Moscow University Press, 2,740 copies, 191 pp/

/Text/ This collection consists of two parts. Part One contains papers dealing with analysis of the problems associated with the effect of rounding-off errors and data in the principal problems of linear algebra: The solution of systems of equations, the computation of eigenvalues and singular numbers, eigensubspaces and root subspaces, etc., as well as with the construction of algorithms for the solution of the Cauchy problem for ordinary differential equations, for the optimization of the selection of nodes at spline interpolation, and for methods of computing multiple integrals. Part Two contains papers dealing with research into methods for the solution of weakly stable and incorrect problems arising in the solution of contraction-type equations, extremal problems, the Cauchy problem for a quasilinear parabolic equation, etc.

The collection is designed for scientific workers, upperclassmen, and graduate students majoring in computational methods.

Table of Contents

1386
CSO: 1870

PUBLICATIONS

PHYSICS OF STRONG DISEQUILIBRIUM PLASMA

Moscow FIZIKA SIL'NONERAVNOVESNOY PLAZMY (Physics of Strong Disequilibrium Plasma) in Russian 1977 signed to press 17 May 77 pp 1-4, 346-347

[Annotation, table of contents, and preface from book by A. A. Ivanov, Atomizdat, 2,200 copies, 352 pages]

[Text] This book examines the phenonema and processes studied in plasma physics in solving the problem of controlled thermonuclear synthesis. The author devotes principal attention to description of linear and nonlinear conditions of plasma instabilities and their influence on plasma containment and heating. The author discusses in detail problems which arise when heating plasma with powerful beams of electrons, as well as possibilities of initiating a thermonuclear reaction with a powerful laser pulse.

This book is intended for specialists in the area of plasma physics as well as graduate students and upper-division undergraduates in the corresponding areas of specialization.

Contents — Page

Preface

This book represents an attempt to encompass a number of interesting phenomena and processes studied by plasma physics, both from a scientific and applied aspect. The rapid development of plasma physics, caused by an attempt to create a controlled thermonuclear reaction, led to the development of new methods of investigation in theory and experiment, methods which have made a substantial contribution to some areas of both physics and chemistry. In particular, study of instabilities of plasma and their nonlinear conditions has proven to be very important for areas which at first glance seem far removed from one another, areas such as astrophysics and solid-state physics, high-temperature chemistry and problems of controlled thermonuclear synthesis, gas discharge physics and the problem of magnetohydrodynamic energy conversion, gas and solid lasers, powerful relativistic electron beams and accelerators.

Many studies have been written on all these problems, but they are frequently of an excessively specialized nature, while there has been no book which would unify the above-enumerated problems, which essentially involve one and the same physical basis. This impedes the development of general concepts on plasma physics and leads to narrower specialization of investigators working in the various areas of plasma physics. Therefore publication of a book such as this seems quite timely.

At the dawn of development of plasma physics, theory and experiment were separated from one another to a great degree, since theoretical research was being conducted chiefly within the framework of linear approximation, while experiments for the most part involved measurement of parameters of developed nonlinear conditions of a given instability. As theory developed methods were created which make it possible to investigate nonlinear or collective effects in plasma, which could be more reliably compared with experimental results. This does not mean that the role of linear approximations in plasma theory has diminished. Linear theory makes it possible not only to determine the thresholds of instabilities but also to predict the influence of unstable oscillations of sufficiently great amplitude on averaged system characteristics. One more important method of studying phenomena in plasma has been developed in the last decade -- numerical modeling, which has proven to be an extremely important addition to theory and occupies and intermediate position between experimental and theoretical investigations.

Thus in order to avoid fragmentary coverage, and, as already mentioned, excessively narrow specialization, we shall describe the phenomena in plasma, not dividing them into linear and nonlinear, utilizing thereby the most adequate methods.

Elementary processes in plasma (Coulomb collisions, collisions between electrons and ions on the one hand and atoms and molecules on the other, and collisions of neutral particles) have been fairly thoroughly studied [1, 2], and therefore they are not specially described in this book.

Various approaches have been utilized in describing phenomena in plasma; the method of investigation is described in a fair amount of detail, but without excessive detailing, which the reader can find in already-published monographs. Principal attention is focused on the interaction of electron and ion beams with a fully-ionized and weekly-ionized plasma, the interaction of high-frequency fields with plasma, the problem of plasma confinement and stabilization in magnetic traps, the problem of turbulent heating of plasma, and the interaction of powerful laser radiation with plasma.

In describing these phenomena, the author discusses the conditions of realization and the present situation principally in the area of controlled thermonuclear synthesis.

The author would like to express his profound thanks to all participants of the seminar held by Academician M. A. Leontovich, at the Atomic Energy Institute imeni I. V. Kurchatov, with whom he has discussed on numerous occasions the problems presented in this book, as well as to T. K. Soboleva for her assistance in preparing the manuscript for publication.

3024
CSO: 1870

PUBLICATIONS

LASER EMISSION IN A TURBULENT ATMOSPHERE

Moscow LAZERNOYE IZLUCHENIYE V TURBLENTNOY ATMOSFERE (Laser Emission in a Turbulent Atmosphere) in Russian 1976 signed to press 29 Nov 76 pp 1-6, 276-277

[Annotation, Table of Contents, Preface and Introduction from book by A. S. Gurvich, A. I. Kon, V. L. Mironov and S. S. Khmelevtsov, Izdatel'stvo Nauka, 1,400 copies, 280 pages]

[Text] The physical bases of the effect of atmospheric turbulence on laser emission are considered in the book. Main attention is devoted to solution of problems related to determination of the mean intensity and intensity fluctuations in laser beams. The effect of turbulence on the phase fluctuations of light waves and distortion of spatial coherence is considered. Methods of determining turbulence parameters by laser emission fluctuations are outlined. Along with theoretical investigations of electromagnetic wave propagation in randomly inhomogeneous media, data on atmospheric turbulence and on methods of describing turbulent fields are presented in the book. Results obtained by approximate numerical methods are presented. Experimental data and generalizations of them, required for practical applications in design of laser systems, are extensively represented. The outline relies to a significant degree on original results obtained by the authors during the past 10 years.

The book is intended for a wide range of readers -- specialists in electromagnetic wave propagation in the atmosphere and in random media, geophysicists and designers of laser systems. It may be of interest for teachers and postgraduate students.

Contents

Preface

Considerable attention has recently been devoted to investigations of laser emission propagation in the atmosphere with regard to the potentially possible applications of laser technology. The effect of random inhomogeneities of the refractive index, caused by atmospheric turbulence, may in some cases be a factor which limits the capabilities of systems utilizing laser emission. The inhomogeneities of the refractive index caused by turbulence are reflected in laser emission parameters to a greater degree, the higher the "quality" of emission, i.e., the less its angular divergence, the greater its spatial and temporal coherence and so on.

A number of monographs is devoted to problems of electromagnetic and sound wave propagation in a medium with random inhomogeneities. However, the results of numerous investigations carried out during the past few years are not reflected in them. Further development of the principal aspect of the considered problem was achieved in some of these papers, which made it possible to apply theory to the case of significant fluctuations of the radiation field, important to practice. Moreover, experimental investigations were carried out, the results of which permit one to find a number of universal functions which cannot yet be obtained by calculation. Finally, there is a large group of papers in which various parameters of laser beams propagated in a turbulent atmosphere are calculated. The most significant of the enumerated new results have been entered in the proposed monograph. It should be noted that many of the results presented in the book can be used without special difficulties for analysis of electromagnetic and sound wave propagation in other randomly inhomogeneously media (for example, sound waves in the atmosphere and ocean, radio waves in the ionosphere, interplanetary medium and so on).

The material of the book mainly relies on investigations carried out at the Institute of Physics of the Atmosphere of the USSR Academy of Sciences and at the Institute of Optics of the Atmosphere of the Siberian Department of the USSR Academy of Sciences.

Chapter 1 of the book was written by A. S. Gurvich, Chapters 2, 5 and 7 were written by A. I. Kon, Chapters 3 and 4 were written by A. I. Kon and S. S. Khmelevtsov and Chapters 7 and 8 were written by A. S. Gurvich and V. L. Mironov. Sections 7 of Chapter 1 and 6 of Chapter 7 were written by V. L. Mironov.

Introduction

Turbulent fluctuations of the refractive index lead to distortion of the light waves propagated in the atmosphere. This phenomenon has long been known to astronomers since it limits the opportunities to observe astronomical objects by using large optical instruments. Study of fluctuation interference occurring during light propagation in the atmosphere has now become especially timely with regard to the extensive use of lasers in optical communications lines, range-finder and goniometric devices and in a number of other applications. Turbulence disturbs the coherence of laser emission and in some cases limits the capabilities of using devices in which coherence is employed (for example, in formation of pencil light beams). Intensity fluctuations occurring during light propagation in the atmosphere cause extensive fading of signals in communications lines. Since the atmosphere is essentially always turbulent, the possibility of interference due to the optical inhomogeneity of the atmosphere must be taken into account when designing optical devices and the system parameters must be selected so as to attenuate this interference to the maximum extent possible. In those cases when interference limits the maximum capabilities of optical systems (for example, resolution), technical requirements may be formulated on the basis of the actually achievable characteristics of the systems when they are operating under atmospheric conditions.

Investigation of wave propagation in a turbulent medium was begun in the USSR by A. M. Obukhov and V. A. Krasil'nikov. Investigation in this direction subsequently continued to be developed actively in the USSR and the results are outlined in two monographs: that of L. A. Chernov (1958) and V. I. Tatarskiy (1959), later translated into English. References to these monographs are contained in almost all publications (both in the USSR and abroad) devoted to wave propagation in a medium with random inhomogeneities of the refractive index. The second monograph of V. I. Tatarskiy "Wave Propagation in a Turbulent Atmosphere" (1967) has also now been translated into English. Along with the mentioned monographs, a large number of experimental and theoretical papers devoted to investigation of laser emission fluctuations during propagation in the atmosphere is published annually, especially abroad; specifically, the special issue of the journal RADIO SCIENCE was published in 1975.

The published monographs are mainly of a theoretical nature and they are outlined at a level not always accessible to engineers. Moreover, the experimental material on laser measurements is not generalized in the published monographs since similar experiments had simply not been conducted by the moment of their writing. Individual special problems are naturally considered in articles published in journals.

Despite the fact that the proposed monograph is devoted to description of light propagation processes in the atmosphere, problems related to molecular absorption and scattering on the aerosol are not considered in it. These problems comprise the contents of V. Ye. Zuyev's monograph "Atmospheric Transparency for Visible and Infrared Beams," published in 1966 and where they are rather fully outlined. Moreover, the fluctuation phenomena caused by turbulence may be considered independently in most cases and they are of independent interest.

The proposed monograph generalizes and considers from a unified view the now available experimental data on fluctuations of the parameters of a light wave propagated in a turbulent atmosphere. The book is primarily addressed to radio engineers, radio physicists and optical specialists and should permit one to calculate fluctuation interference during operation of optical systems with laser emission in the atmosphere.

The theoretical basis of the proposed book is the generally accepted Kolmogorov-Obukhov theory of turbulence and the theory of light propagation in a turbulent atmosphere, developed by V. I. Tatarskiy. The main results of theory required both to understand the physical pattern of the considered propagation processes and to carry out engineering calculations are outlined in the book.

The greatest attention in the book is devoted to experimental results obtained during the past few years with laser light sources. The main data obtained during the past few years by the authors and by collectives of research associates of the Institute of Physics of the Atmosphere of the USSR Academy of Sciences and of the Institute of Optics of the Atmosphere of the Siberian Department of the USSR Academy of Sciences on investigation of phenomena related to "strong fluctuations" are outlined. "Strong fluctuations" occurring on rather long runs were first investigated in work carried out at IFA [Institute of Physics of the Atmosphere] of the USSR Academy of Sciences. There is still no sufficiently developed theory which describes "strong fluctuations." However, concepts of similarity and approximate methods of calculations made it possible to systematize the numerous experimental results for this practically important case and to obtain rather simple empirical relations and graphs suitable for engineering calculations.

Considerable attention was devoted to the calculation of the mean intensity in laser beams and to analysis of defocusing caused by turbulence. A reduction of coherence due to turbulence is rather dependably calculated for practically any possible conditions of propagation in the atmosphere, which has been confirmed by numerous experiments.

Problems on determination of random wandering of beams due to turbulence and also on fluctuation of the luminous flux through receiving apertures of finite dimensions are of important significance for practical applications.

Development of theoretical and experimental investigations upon interaction of turbulence and light waves made it possible to solve the problem of remote sounding of turbulence by means of coherent radiation.

The results of investigations of both Soviet and foreign specialists on fluctuations occurring during light propagation in a turbulent atmosphere, published in the press, were used extensively in the book. The outline of the results of experiments and theoretical calculations is directed not only toward developing a concept of the state of the problem, but also permits one to utilize these data for engineering practice.

In view of the fact that data on turbulence and field structure of the refractive index in the atmosphere is contained in special investigations intended for hydroengineers and geophysicists, a chapter on the structure of turbulence, the typical values of its intensity and methods of determining parameters responsible for the occurrence of fluctuations in a light wave is included in the given monograph.

6521
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PUBLICATIONS

UDC 539.171:539.171.2:539.128.5

USING ELECTRONS TO STUDY NUCLEI

Moscow ISSLEDOVANIYE YADER ELEKTRONAMI in Russian 1977 signed to press 17 Jan 77 pp 1-4, 207-208

[Annotation, Table of Contents and Preface from book by Il'ya Semenovich Gul'karov, Atomizdat, 1800 copies, 208 pages]

[Text] The book deals with the study of nuclei by the method of scattering of high-energy electrons. Examined in greatest detail are processes of elastic and inelastic scattering of electrons by nuclei with excitation of discrete levels, and particularly giant resonance. The author discusses electric and magnetic scattering, scattering by isotopes, and processes that accompany elastic and inelastic scattering of electrons. It is shown that the method of electron scattering is preferable to photonuclear reaction methods for studying giant resonance in nuclei. Nuclear models are briefly discussed. Other problems are also considered -- radiation and dispersion corrections, methods of measuring the spectra of scattered electrons, quasi-elastic scattering with prompt neutron knock-on.

The book is intended for advanced students, graduate students, physicists working in the field of the atomic nucleus, and those who are interested in the latest advances in nuclear physics.

Figures 52, tables 2, references 255.

TABLE OF CONTENTS

PREFACE

This book deals with investigation of the structure of atomic nuclei by the method of scattering of high-energy electrons. The earliest research on nuclear structure was done in the United States, and then in the Soviet Union, France, West Germany, Canada, Japan, Italy and the Netherlands. Research results are presented chiefly in journal articles, and therefore it is necessary to collect the accumulated material in a single book to facilitate the study of the rapidly developing field of nuclear physics.

This book examines problems relating to processes that arise when electrons interact with nuclei. The study of nuclei by electrons is one of the effective methods of studying the structure of nuclei since the nature of interaction of the electron with the nucleus (electromagnetic interaction) is well known. When an electron interacts with a nuclear field set up by nucleons and their currents, scattering of the electron is not accompanied by strong distortion of the nucleus. If consideration is given to radiation and dispersion corrections (the latter are associated with virtual excitation of intermediate states of the nucleus), such interaction is elastic scattering. In the case of inelastic scattering, we know only the lepton part of the vertex in the diagram that describes the interaction of the electron with the nucleus. The advantage of using electrons as compared with photons is that in the case of real photons, the momentum q transmitted to the nucleus is determined by the energy ε transferred to the nucleus, whereas in the case of virtual photons (electrons), different values of q are admissible. This enables us to study the matrix elements of the distributions of charges and currents in the nucleus in a large interval of transmitted momenta.

Chapter 1 examines elastic scattering of electrons by nuclei, which is one of the precision methods of measuring the radius of a nucleus and the charge density distribution in nuclei. By studying elastic scattering of electrons by nuclei we can explain the influence of neutrons on charge distribution in nuclei. This chapter also examines scattering of electrons with consideration of the magnetic and quadrupole moments of nuclei, as well as the processes that accompany elastic scattering of electrons by nuclei (radiation and dispersion corrections). Methods of measuring the spectra of scattered electrons are considered here also.

Chapter 2 deals with excitation of discrete levels of nuclei, which may take place with inelastic scattering of electrons. By analyzing measured form factors, one can determine many characteristics of nuclei in the excited state -- reduced probabilities of transitions, vibrational parameters, transition radii and so forth.

Chapter 3 is devoted to one of the urgent problems of nuclear physics -- investigation of giant resonances in nuclei. An examination is made of electric (dipole and quadrupole) and magnetic giant resonances in nuclei. The main feature of the method of electron scattering is the possibility of measuring the form factor of giant resonances as a function of the transmitted momentum. The mechanism of this excitation is explained by using different models of nuclei: Goldbarger-Teller, Danos and Greiner, the shell model and others. This same chapter gives the results of measurements made by the method of inelastic scattering along with their theoretical interpretation.

In Chapter 4 an examination is made of quasielastic scattering of electrons by nuclei. By investigating quasielastic scattering we can study the momentum distribution of nucleons, determine their binding energy and get an idea of the correlation between nucleons. An examination is also made of reactions (e, e'x) in which the scattered electron and the knock-on particle from the nucleus are simultaneously registered.

The conclusion contains a brief discussion of the outlook for using electron linacs on high energies to study the structure of nuclei.

The author is sincerely grateful to Professor G. Ya. Umarov for continued interest, support and attention in the work, and also to reviewers Candidate of Physical-Mathematical Sciences S. F. Semenko and Yu. I. Titov for their many valuable comments that were conducive to improvement of the content of this book.

6610
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PUBLICATIONS

STATICS AND DYNAMICS OF ROCKET ENGINES

Moscow STATIKA I DINAMIKA RAKETNYKH DVIGATEL'NYKH USTANOVOK (Statics and Dynamics of Rocket Engines, Part I) in Russian 1978 Vol 1 pp 220-221

[Table of contents from book by Ye. B. Volkov, T. A. Syritsyn and G. Yu. Mazing, Mashinostroyeniye, 221 pages]

[Text] Contents Page

9082
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PUBLICATIONS

COMPUTER HARDWARE FOR STATISTICAL MODELING

Moscow VYCHISLITEL'NAYA TEKHNIKA DLYA STATISTICHESKOGO MODELIROVANIYA (Computer Equipment for Statistical Modeling) in Russian 1978 signed to press 29 Aug 77 pp 2, 8, 308-310

[Annotation, excerpt from introduction, and table of contents from book by V. N. Chetverikov, E. A. Bakanovich, and A. V. Men'kov, Sovetskoye Radio, 11,250 copies, 312 pages]

[Text] This book deals with problems of building controlled probability elements and controlled probability converters, which constitute the principal structural elements of stochastic machines and models. The authors examine questions pertaining to selection of the parameters of these devices, evaluation of the accuracy of their operation, etc. The authors select the most expedient structure of a stochastic model for investigation of complex systems, describe the circuitry of the principal component units of the model and present modeling results.

This book is intended for persons dealing with development of probability devices, control systems, as well as for undergraduates and graduate students at higher educational institutions.

[Excerpt] Introduction

This book consists of an introduction and six chapters.

The first chapter deals with examination of various aspects of implementation of the method of statistical tests on a general-purpose computer. This chapter also contains information on methods of forming flows of random numbers on a computer.

The second chapter examines the structural features of existing experimental models of stochastic and analog computers which implement methods of statistical tests: models of queuing systems, models of network systems, etc.

The third and fourth chapters deal with investigation of uncontrolled and controlled probability elements, with principal attention focused on analysis of original circuitry of probability elements.

The fifth chapter presents results of investigation of controlled probability converters, both original (recently developed by the authors) and ones utilized in experimental models of stochastic devices.

In the sixth chapter the authors examine the rational structure of a stochastic model for examination of complex systems, substantiate the expediency of constructing aggregated stochastic models and describe unique aggregated stochastic devices.

Knowledge in the area of probability theory and computers at the college level is adequate for reading this book.

This book is intended for persons working with the development of probability devices, control systems, as well as for undergraduates and graduate students at higher educational institutions.

Chapters three through six can be read independently of the first two chapters.

Contents

28 FEBRUARY 1979 (FOUO 12/79) 3 OF 3

3024
CSO: 1870

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