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TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY
PHYSICAL SCIENCES AND TECHNOLOGY
(FOUO 32/79)

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PHYSICAL SCIENCES AND TECHNOLOGY

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CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

UDC 002.63:681.3.004.14

DESIGN OF A DATA TRANSMISSION NETWORK FOR SCIENTIFIC-TECHNICAL INFORMATION

Moscow NAUCHNO-TEKHNICHESKAYA INFORMATSIYA. SERIYA I. ORGANIZATSIYA I METODIKA INFORMATSIONNOY RABOTY in Russian No 3, 1979 pp 1-3

[Article by A. Z. Kulebyakin, Ye. V. Kiulo, submitted 4 Apr 78]

[Text] The constant increase in the volume of scientific-technical information poses the acute problem of automating information services and of increasing sharply the labor productivity of their workers.

The improvement of the existing system of scientific-technical information, directed toward the fuller satisfaction of social production requirements is, on the one hand, an objective necessity determined by the progress of science and engineering, while on the other hand, it became real only because of the progress of science and engineering that led to a radical renewal of the material-equipment base of the government system of scientific-technical information.

At present, work is being done on the creation of a network of automated centers NTI [Scientific and technical information] (SATsNTI) that makes it possible to store masses of information in a computer memory efficiently; provide direct access to this information to many users; the search, transmission and delivery of information over required addresses between users and computers, as well as between computing machines of information centers.

Joining individual automated information centers (AITs) into a network is a new organizational form which makes possible a considerable increase in the use of expensive computer equipment, communications facilities and operational polygraphy.

The creation of a network of automated NTI centers will make it possible to implement the efficient separation of AITs resources by redistributing informational flows, eliminating unjustified duplication and storage of information, efficient utilization of the AITs computer memory, and the expansion of the possibilities of each AITs on servicing users, as well as by organizing special servicing centers. The following resources in the SATsNTI can be separated in the initial stage: data (i.e., information stored in individual centers); various special equipment (for example, facilities for storing a large volume of information) and in the following stages -- developed programming systems for the solution of problems of search, selection and sorting of data; computer capacities (i.e., computers and their operational systems).

A correctly organized AITs network will make it possible to present the best possibilities for organizing and utilizing reference-informational bodies of data and solve the problems of the qualitative improvement of providing information to consumers no matter how far away they are.

The network user will have the possibility of direct access to all data stored in the "distributed automated document data bank" of the SATsNTI for satisfying data requirements in a minimum of time with maximum completeness and authenticity.

It should be noted that by virtue of a number of specific features of the NTI network, the designing of the SATsNTI is entirely practicable with the existing computer and communications facilities and, to a certain extent, does not depend on the creation of a computer center network.

With some similarity of technical implementation of an NTI network and a computer center network, consisting of the fact that in both cases the basic technical elements are elements of computer equipment and communications equipment, the difference in the goals in creating them should be noted.

The basic goal of creating an NTI network is to present the user with direct access to the distributed mass of data on documents stored in the data banks of the AITs network.

The basic goal of creating a computer center network is to divide the computer capacities making it possible for any computer in the network to utilize the computer capacity of any number of computers among the total number of computers in the network.

A necessary condition for the functioning of the NTI network is the standardization of the information document form and not the methods of processing the data (in structure, composition, content, names and codes) unlike the computer center network.

It is this very difference in goals that makes it possible to tie the design of the SATsNTI to the creation of a government system of computer centers since, in designing an NTI network on the basis of AITs computers, the solution of the problem of organizing the interaction of computers for the purpose of the full separation of computer capacities is not obligatory. In this connection, the primary goal of the SATsNTI, along with the creation and improvement of automated NTI centers, is the solution of the problem of designing a data transmission network that offers NTI users direct access to the data banks of the AITs network.

The NTI network can be divided conditionally into three levels:

-- automated information centers;

-- a data transmission network;

-- user terminals.

The efficiency of solving the problem of designing an NTI network depends to a great extent on the chosen structure of the data transmission network, which is determined by the goals and principles of creating the NTI network described in detail in papers [1, 2] .

Since computers functioning in the network demand high requirements of communications channels from the standpoint of reliability and transit capacity, and inasmuch as the cost of communications facilities is comparatively high, one of the basic principles in designing a data transmission network is the most economical and efficient utilization of communications channels, which eliminates the approach based on assigned "one-to-one" channel connection.

The most efficient utilization of communications channels is achieved by organizing a communications network with switching packets of messages which makes it possible to achieve the maximum transit capacity of the data transmission network with the existing stochastic distribution of the flow of inquiries-messages of its subscribers. Moreover, the choice of such a type of SATsNTI communications network responds to the basic directions of the development of a general government system of data transmission (OGSPD) and international communications networks.

An analysis of data transmission networks in the world indicates that the best approach to the problem of creating an NTI network is to divide the network components according to their functional characteristic.

If this principle is adhered to, then the basic members of the data transmission network will be junction installations (US) and message switching centers (TsKS). This organization of the structure of the data transmission network will make it possible to free AITs computers, intended for doing technological operations on processing data, from operations related to transmitting messages over the network.

Junction installations serve to connect AITs computers and user terminals directly to message switching centers.

The basic functions of SATsNTI junction installations are generally as follows:

-- joining AITs computers and terminals to TsKS;

-- control terminals and AITs computers;

-- control communications between the terminal and AITs computers directly;

-- convert to the standard format of the network;

-- breakdown and restoration of messages;

-- control flow and control overloads;

-- control communications channels of AITs computers and terminals.

The message switching center is the basic element of the data transmission network and serves to transmit information received over the optimal route to the information receiver.

The basic functions of the TsKS are:

-- transmission of messages (packets of messages);

-- routing of messages (packets of messages);

-- detection and correction of communications errors;

-- collection of statistical data and their transmission to the SATsNTI coordinating center;

-- control of communications lines.

Network "junctions" are organized of the basis of junction installations and message switching centers.

The design of a network junction is shown in Fig. 1.

Fig. 2 shows one possible version of organizing the NTI network by means of junctions shown in Fig. 1.

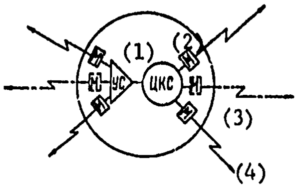

Fig. 1

1. US -- junction installation
2. message switching center ЦКС
3. modem
4. communications center

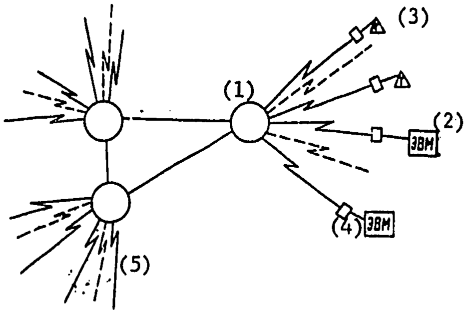

Fig. 2

1. network center
2. computer
3. remote terminal
4. modem
5. communications channel

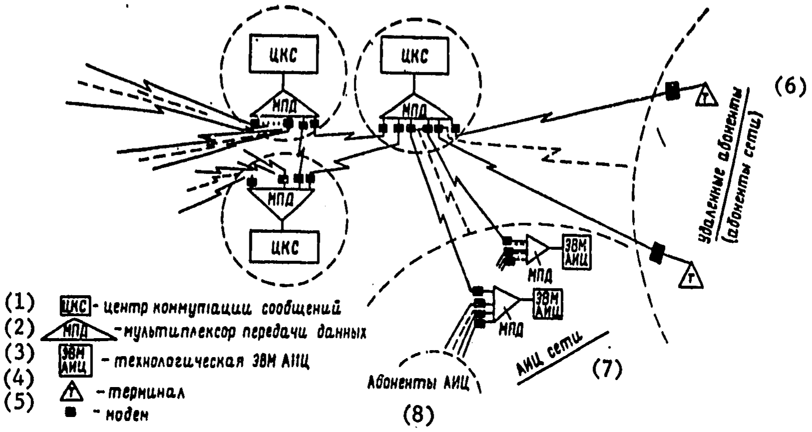

Fig. 3

1. message switching center
2. data transmission multiplexer
3. technological AITs computer
4. terminal
5. modem
6. remote subscribers (network subscribers)
7. network AITs
8. AITs subscribers

The structure of the data transmission network presented meets the basic principles of integration, specialization, compatibility, adaptivity and accessibility.

In particular, in designing an NTI network based on AITs, equipped with a single type of computer, the basic functions of a network junction, necessary for the direct access of subscribers to masses of data about documents when developing corresponding software, may be placed on series manufactured computers equipped with data transmission multiplexers.

If the structure shown in Fig. 2 is transformed to the structure shown in Fig. 3, network junctions will only fulfill the functions of a commutator that provides for message transmission between a subscriber and an AITs computer and between AITs computers.

In the process of improving the software and hardware for the basic functions imposed on the NTI data transmission networks, the efficiency of network functioning will increase, insuring the implementation of more perfect forms and kinds of informational servicing, facilitating an increase in the efficiency of satisfying the requirements of the network subscribers.

Conclusions

The proposed structure of the design of the data transmission network makes it possible to provide the following:

- -- interrelation between user terminals with all AITs computers within the NTI network;
- -- connection to the NTI network of basic computers on whose bases data banks on documents are organized without loading them with appropriate functions;
- -- stage-by-stage implementation of the SATsNTI based on available resources and equipment possibilities;
- -- efficient utilization of communications channels;
- -- unit increase in the capacity of the NIT network by increasing the number of "junctions" and connecting AITs and user terminals to it;
- -- creation of a heterogenous network, i.e., a network that may use various types of computers;
- -- compatability with the general government data transmission system being created in the country and the communications networks abroad;
- -- adaptivity of the NTI network.

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CSO: 1870

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

UDC [002.2:159.9](049.3)

BOOK PUBLISHED ON PSYCHOLOGICAL PROBLEMS IN DOCUMENTALISTICS

Moscow NAUCHNO-TEKHNICHESKAYA INFORMATSIYA, SERIYA 2. INFORMATSIONNYYE PROTSESSY I SISTEMY in Russian No 3, 1979 pp 37-38

[Book review by E. V. Afanas'yev of the book "Voprosy Kibernetiki, Vyp 39. Dokumentalistika i psikhologiya" (Problems of Cybernetics, No 39. Documentalistics and Psychology). Moscow, Scientific Council for the Complex Problem "Cybernetics" of the USSR Academy of Sciences, 1978]

[Text] This collection is devoted to theoretical and practical aspects of psychological documentalistics--a new discipline that studies distinctive features in the creation and perception of documents by man. Consideration of this factor becomes extremely necessary in contemporary organizational systems because of the high intensity of documental information flows. Unfortunately, up to now there have not been so many works published in our country that have been devoted to the psychological aspects of documentalistics, and therefore the collection is of great interest.

The materials published in the collection are divided into three parts. General problems of psychology in documentalistics are examined in the first section. The article of G. G. Vorob'yev entitled "Psychological documentation: theory and problems," which opens that section, is devoted to pragmatic and semantic features of the intercourse of the authors of documents with recipients. In the article an attempt has been made to classify the situations of intercourse of people through documents, and distinctive features of test and clearing information systems are pointed out. Yu. A. Novikov, in the article "Psychological properties of scientific information," notes a number of contradictions arising in the study of information for a creative purpose, that is, in seeking solutions of creative tasks. The author distinguishes such properties of scientific information as heuristicity and progressiveness, which actively influence the creative thinking of man and must be taken into consideration in the informational servicing of specialists. Devoted to the influence of psychological factors on the stability of form of a document was the article of M. G. Gaaze-Rapoport and A. N. Sokovaya entitled "Psychological factors in documentation and their use," in which the social properties of documents, questions of terminology and the properties of documentary communications also were examined.

The first section ends with the article of B. V. Yakushin, "Thinking that generates a text." In the article an analysis is given of informational models of the brain and a method of constructing individual consciousness on the level of informational processes is presented.

The second section of the collection, which is devoted to the perception and processing of documental information, is opened by the article of O. A. Kuznetsov, A. N. Korenev and L. N. Khromov entitled, "Speed reading. Experience in teaching, problems and prospects." The authors present the basic principles of speed reading, present the procedure and report the results of teaching speed reading. In the article of M. V. Khanin and E. V. Khanina on "Systems approach to the process of perception and delivery of information," a report is presented on experiments to determine the ability of man to form or perceive proposals. A value inverse to the activity of that process is called the natural frequency of perception or delivery of information. The article by A. V. Antonov on "Reading as a process of text perception" contains the results of investigations of perception of a text as a function of its space-geometric characteristics. Tests with different length of line and space between letters were used in the experiments, and also with and without paragraph indentations. The article of B. V. Apukhtin and A. M. Shakhnarovich entitled "Some problems of remembering a text" was devoted to consideration of the completeness and level of knowledge of the recipient during construction of the semantic structure of a text. The authors examined conditions in which perception of a text is accompanied by obtaining new knowledge and the formation of new levels of generalization of old knowledge. In the article of Yu. L. Trofimov entitled "Experimental investigations of processes of perception of drawings and diagrams," data obtained in an experimental investigation of the perception of drawings and schematic depictions of technical objects were presented. The persons being tested were divided into several groups and presented drawings with different exposure time, and the work of the oculomotor system was recorded.

In the article of Ye. V. Yesipova entitled "Some psychological aspects of the perception of choral parts," experimental results were presented which can be also extended to other texts with partitur reading, that is, those where the recipient perceives simultaneousl several lines without reducing the prescribed rate of reading. This article concluded the second section.

The third section of the collection consists of two articles. In the article of M. L. Kolchinskiy entitled "Psychological aspects in documental automated scientific and technical information systems [ASNTI], a point of view is presented on the problem of the "growth" of ASNTI's and on the essence of informational needs, some information is presented on the psychological aspects of the work of specialists studying ASNTI's, and information about distinctive features of the filling out of feedback cards by subscribers. The second article, "Analysis of factors affecting the evaluation of documents by ASNTI subscribers," was written by M. L. Kolchinskiy with T. M. Narskaya. The authors present the results of analysis of feedback cards of the "Setka" ASNTI, containing an evaluation of the information by subscribers of the system. The factors affecting the evaluation of information are broken down into two groups: factors relating to the sphere of professional activity and the psychological properties of the user, and factors relating to the sphere of the functioning of the system.

As is evident from this brief survey, in the collection a fairly wide range of questions is examined and interesting results of investigations of psychological aspects of documentalistics are presented. At the same time, many positions of the articles testify to a need for thorough investigations of psychological problems, in particular, such problems as: the interaction of scientists and specialists with information workers in the process of providing information about investigations and developments; pyschological features of the informational preparation of administrative decisions; distinctive features in considering the human factor in the selection of scientific and technical achievements from informational materials. It is necessary to expand the range of investigations of the psychological aspects of informational activity, attracting various specialists to those investigations. It is assumed that the Scientific Council for the Complex Problem "Cybernetics" of the USSR Academy of Sciences, which issued the reviewed collection, can head that work on a countrywide scale.

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CSO: 1870

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.391.2

INFORMATIONAL CAPACITIES OF THE SETS OF PARAMETERS OF RADAR SIGNALS VARYING STOCHASTICALLY WITH TIME

Kiev IZVESTIYA VUZOV SSSR, RADIOELEKTRONIKA in Russian No 1, Jan 79 pp 59-64

[Article by G. G. Kosenko, submitted 19 Dec 1977]

[Text] The author presents his evaluations of informational capacities of the sets of parameters, both dependent and independent, changing stochastically with time from the position of the adequacy of the amount of information supplied by them for dividing a given sequence of objects into classes. He gives the analyzing structures which ensure the selection of parameters from the position of adequacy and formulates conditions for the observation interval under which the prescribed set of parameters ensures the obtaining of minimally sufficient amount of information.

In the majority of practical cases, in order to obtain information about statistical properties of various classes of objects, not just one parameter, but, as a rule, a set of parameters is used. The use of sets of parameters for obtaining information about various classes of radar objects makes it necessary to evaluate their informational capacities.

In this work, the ideas presented in [1] are developed further for a case when sets of parameters varying stochastically with time are used for the purpose of identifying various classes of objects.

In constructing a theory for the evaluation of informational capacities of sets of parameters varying stochastically with time, main attention will be given to the determination of the effect of the observation time, the number of used parameters in the set, and their statistical connection on the amount of information provided by them and on their informativeness from the position of adequacy [2].

Let us assume that we are given a sequence of classes of radar surveillance objects $A_1, \ldots, A_N$ and their a priori probabilties $p_1, \ldots, p_N$ of appearance in the radar surveillance zone. We shall also assume that we are given a certain set of n-parameters $\bar{\xi}(t)=\{\xi_1(t),\dots,\xi_n(t)\}t\in[0,T]$ and each class of objects A_k, $k=1, \dots, N$ is described in the language of a given set $\xi(t)$ by a probable measure μ_k, $k=1, \dots, N$. We shall also assume that the measures μ_k, $k = 1, \dots, N$ are absolutely continuous in relation to one another for the entire field of events pertaining to the behavior of $\xi(t)$ over the entire surveillance interval $[0,T]$.

For further examination, let us divide interval $[0, T]$ for each i-th parameter of $\bar{\xi}_i(t)$, $i=1, \dots, n$ into m_i non-intersecting intervals $\Delta t_{1i}, \dots \Delta t_{mi}$ and such that $\sum_{l_i=1}^{m_i}\Delta t_{li}=T$ when all $i = 1, \dots, n$. Intervals Δt_{li} are selected in such a way that the processes $\xi_{1i}(t), \dots, \xi_{mi}(t)$ are independent and the sets of the parameters on the n-dimensional parallelepipeds of independence $\Delta t_{l1}\times\dots\times\Delta t_{ln}=\Delta_{l1,\dots,ln}$ are also independent among themselves.

Definition 1. Let us call the magnitude

$$\tilde{a}_{kj}(\Delta_{l1,\dots,ln};\ x_1(t_1),\dots,x_n(t_n))=\frac{d\mu_k}{d\mu_j}(x_1(t_1),\dots,x_n(t_n)),\ t_1,\dots,t_n\in\Delta_{l1,\dots,ln} \qquad (1)$$

informativeness of the set of parameters $\xi_1(t),\dots,\xi_n(t)$ for class A_k in relation to class A_j, $j\neq k = 1, \dots, N$ on the parallelepiped of independece $\Delta_{l1,\dots,ln}$.

Using (1), it is easy to write an expression for the informativeness of the set of parameters $\bar{\xi}(t)=\{\xi_1(t),\dots,\xi_n(t)\}$ in surveillance interval $[0,T]$ for class A_k in relation to class A_j, $j\neq k = 1, \dots, N$ which has the following form:

$$\tilde{\alpha}_{kj}(T;x_1(t_1),\dots,x_n(t_n))=\prod_{l_1=1}^{m_1}\dots\prod_{l_n=1}^{m_n}\tilde{\alpha}_{kj}(\Delta_{l1,\dots,ln};\ x_1(t_1),\dots,x_n(t_n)). \qquad (2)$$

When the parameters are independent among themselves, expression (2) assumes the following form:

$$\tilde{\alpha}_{kj}(T;x_1(t_1),\dots,x_n(t_n))=\prod_{l_1=1}^{m_1}\dots\prod_{l_n=1}^{m_n}\prod_{i=1}^{n}\alpha_{kj}^{(i)}(\Delta t_{li};\ x_i(t_{li})). \qquad (3)$$

where $\alpha_{kj}^{(i)}(\Delta t_{li};\ x_i(t_{li}))=\frac{d\mu_k^{(i)}}{d\mu_j^{(i)}}(x(t)), t\in\Delta t_{li}$ is the informativeness of the i-th parameter of $\xi_i(t)$, $i = 1, \dots, n$ in the interval of independence Δt_{li} for class A_k in relation to class A_j, $j\neq k = 1, \dots, N$.

The amount of information supplied by the given set of parameters $\xi(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$ about the k-th class of radar objects is defined by the expression [2,3]

$$I_k(x_1(t), \ldots, x_n(t)) = H(p_k) - H(q_k(x_1(t), \ldots, x_n(t))), \qquad (4)$$

where

$$q_k(x_1(t), \ldots, x_n(t)) = \frac{p_k}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\sum\limits_{l_1=1}^{m_1} \cdots \sum\limits_{l_n=1}^{m_n} \ln \tilde{\alpha}_{kj}(\Delta_{l1,\ldots,ln}; x_1(t_1), \ldots, x_n(t_n))}}. \qquad (5)$$

The obtained expressions (1)-(4) are general in nature and are true for any processes, including nonsteady-state processes.

However, for finding expressions for the amount of information and informativeness which depend explicitly on the surveillance time, we shall limit ourselves to the examination of a class of steady-state processes. Such processes are used widely in statistical radio engineering for describing real signals reflected from various classes of objects. On this basis, we shall assume that $\Delta_{li} = \Delta$ for all i = 1, ..., n, i.e., $\Delta_{l1,\ldots,ln} = \Delta^{ti}$ and that the informativeness (1) of the set of parameters $\xi_1(t), \ldots, \xi_n(t)$ on n-dimensional cube Δ^n does not depend on time

$$\tilde{\alpha}_{kj}(\Delta_{l1,\ldots,ln}; x_1(t_1), \ldots, x_n(t_n)) = \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,)). \qquad (6)$$

Then expression (5), with consideration for (6), assumes the following form:

$$q_k(x_1(\,), \ldots, x_n(\,)) = \frac{p_k}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}}. \qquad (7)$$

On the basis of the generalized measure (4) with consideration for (7), it is possible to construct various measures of radar information [2,3] for determining the amount of information supplied by a given set of parameter.

1. Kotel'nikov's measure of radar information

$$I_k^{(0)}(\,) = \overset{\max}{\text{макс}} \left\{ \frac{p_k}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}} \right\} - \overset{\max}{\text{макс}} \{p_k\}.$$

2. Shannon's measure of radar information

$$I_k^{(1)}(\,) = \ln \frac{1}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}}. \qquad (8)$$

3. Kul'bak's measure of radar information

$$I_k^{(2)}(\,) = \ln \frac{1 - p_k}{\sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}}.$$

4. Bayes' measure of radar information

$$I_k^{(3)}(\,) = p_k \left[\frac{1}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}} - p_k \right].$$

5. Fisher's measure of radar information

$$I_k^{(4)}(\,) = \ln \frac{p_k^2}{p_k + \sum\limits_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))}} \times$$

$$\times \ln \left[p_k + \sum_{j \neq k=1}^{N} p_j e^{-\left[\frac{T}{\Delta}\right]^n \ln \tilde{\alpha}_{kj}(\Delta^n; x_1(\,), \ldots, x_n(\,))} \right].$$

The constructed measures of radar information make it possible to determine the amount of information supplied by a given set of parameters depending on the surveillance time, the number of used parameters, and their statistical connections and a priori probabilities of the appearance of objects of given classes in the zone of radar surveillance.

By analogy with [1], we shall introduce the concept of adequate informativeness.

Definition 2. The set of parameters $\xi(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$ for class A_k is called sufficiently informative in relation to class A_j, $j \neq k = 1, \ldots, N$ in the interval $[0,T]$ if

$$\tilde{\alpha}_{kj}(T;\, x_1(\,),\ldots,x_n(\,)) \geqslant \Theta_k = \left(\frac{1-p_k}{p_k}\right)^2,\quad k=1,\ldots,N. \tag{9}$$

Then, using Definition 2, we shall formulate a condition with whose fulfillment the set of parameters $\xi(t)=\{\xi_1(t),\ldots,\xi_n(t)\}$ supplies a sufficient amount of information [2] about the k-th class of objects. We shall formulate the condition in the form of a statement omitting its proof.

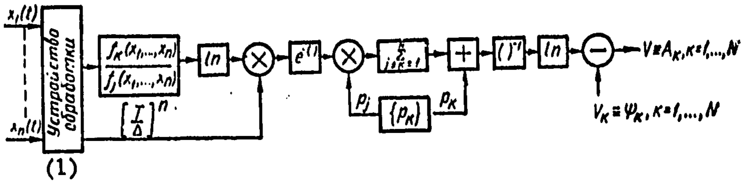

Figure 1
Key: 1. Processing device

Theorem 1. Let $\Delta_{l_1,\ldots,l_n}=\Delta^n$ be the n-dimensional cube of independence of the set of dependent parameters $\bar{\xi}(t)=\{\xi_1(t),\ldots,\xi_n(t)\}$, and the informativeness of this set of parameters on Δ^n does not depend on the time $\tilde{\alpha}_{kj}(\Delta_{l_1,\ldots,l_n};\, x_1(t_1),\ldots,x_n(t_n))=\tilde{\alpha}_{kj}(\Delta^n;\, x_1(\,),\ldots,x_n(\,))$. Then, if the condition

$$\tilde{\alpha}_{kj}(\Delta^n;\, x_1(\,),\ldots,x_n(\,)) \geqslant e^{2\left[\frac{T}{\Delta}\right]^{-n}\ln\frac{1-p_k}{p_k}}.$$

is fulfilled for class A_k in relation to class A_j for all $j \neq k = 1,\ldots,N$, then the amount of information supplied by this set of parameters in the surveillance interval [0,T] is not less than the minimally sufficient amount

$$I_k(x_1(\,),\ldots,x_n(\,)) \geqslant \Psi_k,\quad k=1,\ldots,N,$$

where Ψ_h is the level of the minimally sufficient amount of information [2].

On the basis of Theorem 1 and expression (9), it is possible to construct analyzing devices both with respect to the criterion of the amount of information, and with respect to the criterion of informativeness.

A block diagram of an analyzing device constructed on the basis of Shannon's radar measure (8) for sets of interdependent parameters is shown in Figure 1. In Figure 1 and all subsequent figures, $f_k(x_1,\ldots,x_n),\ k=1,\ldots,N$ designates the distribution density of Class A_k, k = 1,... N.

An analyzing device constructed on the basis of the criterion of informativeness (9) for a set of interdependent parameters is shown in Figure 2a.

The expression for informativeness (3) for parameters which are not dependent among themselves assumes the following form under the conditions of Theorem 1:

$$\tilde{\alpha}_{kj}(T; x_1(\ ), \ldots, x_n(\ )) = e^{\left[\frac{T}{\Delta}\right]^n \sum_{i=1}^{n} \ln \alpha_{kj}^{(i)}(\Delta; x_i(\ ))} . \qquad (10)$$

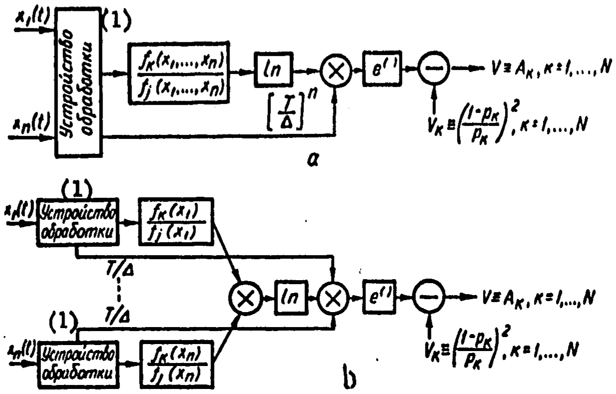

Figure 2
Key: 1. Processing device

A block diagram of an analyzing device constructed on the basis of (9) with consideration for (10) is shown in Figure 2b.

By analogy with [1], it is possible to introduce the concept of equivalent informativeness for sets of independent and dependent parameters. Moreover, by using the concept of minimally sufficient informativeness [2], it is possible to examine the influence of the surveillance time, the number of parameters used in the set, and their statistical connections on the amount of information supplied by a minimally sufficient informative set of parameters.

Another important problem of great practical importance is the determination of the necessary surveillance time ensuring the obtaining of a minimally sufficient amount of information about the class A_k, $k = 1, \ldots, N$ with the aid of the given set of parameters $\bar{\xi}(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$. In order to solve this problem, let us formulate the conditions imposed on the surveillance interval [0,T] which have to be satisfied for the sets of both dependent and independent parameters to ensure the obtaining of both a minimally sufficient amount of information. We shall formulate the conditions in the form of statements omitting the proofs.

Theorem 2. Let us assume that the informativeness of any parameter from the given set of mutually independent parameters $\xi(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$ in the interval of independence Δ for class A_k, $k = 1, \ldots, N$ is constant

$$\alpha_{kj}^{(i)}(\Delta;\, x_i(\;)) = \alpha_k(\Delta;\, x(\;))$$

at all $j \neq k = 1, \ldots, N$. Then, if

$$\frac{T}{\Delta} = \sqrt[n]{\frac{1}{n}\,\frac{\ln\left(\frac{1-p_k}{p_k}\right)^2}{\ln\alpha_k(\Delta;\, x(\;))}}, \tag{11}$$

then the given set of parameters $\xi(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$ is minimally sufficiently informative in the surveillance interval [0,T].

Theorem 3. Let us assume that the informativeness of a set of dependent parameters $\xi(t) = \{\xi_1(t), \ldots, \xi_n(t)\}$ on an n-dimensional cube of independence Δ^n for the class A_k, $k = 1, \ldots, N$ is constant

$$\tilde{\alpha}_{kj}(\Delta^n;\, x_1(\;), \ldots, x_n(\;)) = \tilde{\alpha}_k(\Delta^n;\, x_1(\;), \ldots, x_n(\;))$$

at all $j \neq k = 1, \ldots, N$. Then if

$$\frac{T}{\Delta} = \sqrt[n]{\frac{\ln\left(\frac{1-p_k}{p_k}\right)^2}{\ln\tilde{\alpha}_k(\Delta^n;\, x_1(\;), \ldots, x_n(\;))}}, \tag{12}$$

then the given set of parameters is minimally sufficiently informative in the surveillance interval [0,T].

Let us compare the necessary surveillance time for sets of independent and dependent parameters. For this comparison, let us assume that

$$\frac{\ln\left(\frac{1-p_k}{p_k}\right)^2}{\ln\tilde{\alpha}_k(\Delta^n;\, x_1(\;), \ldots, x_n(\;))} = \frac{\ln\left(\frac{1-p_k}{p_k}\right)^2}{\ln\alpha_k(\Delta;\, x(\;))} = \delta_k.$$

Then, expressions (11) and (12) assume, respectively, the following forms:

$$\frac{T}{\Delta}=\sqrt[n]{\frac{1}{n}\delta_k}, \qquad (13)$$

$$\frac{T}{\Delta}=\sqrt[n]{\delta_k}. \qquad (14)$$

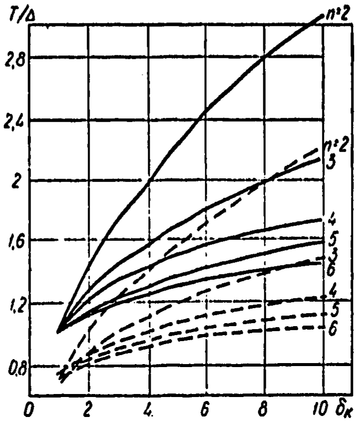

Figure 3

Curves of the comparison of the necessary surveillance time for ensuring a minimally sufficient informativeness for sets of both dependent and independent parameters plotted on the basis of expressions (13) and (14) are shown in Figure 3. Solid lines in Figure 3 shows the dependence T/Δ for a set of dependent parameters and interrupted lines show the dependence for a a set of independent parameters. It can be seen from the curves that, as n grows, the time T/Δ necessary for ensuring a minimally sufficient informativeness decreases both for dependent and for independent parameters.

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ELECTRONICS AND ELECTRICAL ENGINEERING

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APPLICATION OF THE 'EQUIVALENT ELECTRON STREAM' METHOD TO SOLVING DYNAMIC PROBLEMS OF O-TYPE DEVICES

Kiev IZVESTIYA VUZOV SSSR-RADIOELEKTRONIKA in Russian No 1, Jan 79 pp 44-47

[Article by Ye. D. Belyavskiy, submitted 2 Dec 77]

[Text] The "equivalent electron stream" method is generalized in application to the dynamic problems of O-type microwave devices.

In this work, the "equivalent electron stream" method is generalized in application to the dynamic problems of O-type microwave devices. In this case, just as in solving the problems of focusing, this method makes it possible to reduce substantially the counting time on an electronic digital computer by excluding local interactions of individual particles from consideration.

The radial motion of electrons in an axially symmetric stream propagating along axis z in a cylindrical system of coordinates (r, θ, z) is described by the following equations [1]:

$$\frac{\partial u}{\partial z} = \frac{1}{v_z}\{r\dot{\Theta}^2 + \eta[E_r + E_{rc} + \dot{\Theta}B_z]\},$$
$$\frac{\partial q}{\partial z} = \frac{u}{v_z}, \qquad r = |q|, \tag{1}$$

where $u=u(z, r_0, \varphi_0)$; $q=q(z, r_0, \varphi_0)$; r_0 is the initial value of r (at z = 0); $\varphi_0=\omega t_0$; t_0 is the initial time; v_z is the longitudinal velocity; θ(z,r) is the azimuthal velocity; $B_z(z,r)$ is the longitudinal component of the magnetic induction of the focusing field; E_r is the radial component of the space charge field; E_{rc} is the radial component of the external high-frequency field.

An electron stream is, in its nature, a continuous medium characterized by the current density j(r,z,t) and the volume charge density ρ(r,z,t). These values are smoothly changing functions of r in spite of the fact the the motion of concrete electrons in such a stream and their interaction could be extremely intricate.

The values of j and ρ can be approximated with a sufficient degree of accuracy (at fixed t and z) by step laws of changes with a small number of steps, i.e., at each point along axis z, the stream can be considered (from the viewpoint of the created field) as laminar with a small number of layers (N). In this case, the computation of the motion of the system $M = M_1M_2$ of electrons, where M_1 is the number of divisions by the radius, and M_2 is the number of divisions by the initial time ($M_1 \gg N$), amounts to solving the equations of electron motion in a "prescribed" field of an equivalent laminar stream whose parameters (currents of layers and their radii) are integral (smoothed) functions of motion M of test electrons. In view of the fact that $M_1 \gg N$, the counting time decreases substantially (approximately by M_1/N times), and the shortcomings connected with the local nature of the interaction of enlarged particles are eliminated.

Let us assume that $r_{max}(z)$ is the maximum value of the function $r(z, r_0, \varphi_0)$ at the point z along the axis of the stream. Let us use the following designations: $b_{-m}(z)$ -- slowly changing upper radius of the m-th layer ($m = 1, 2, \ldots, N$). Let us assume that $b_{-N} = r_{max}(z)$. Then the division into layers (steps) at each point along the axis z can be given in the following form:

$$b_{-m}(z) = \frac{r_{max}(z)}{b_{-N0}} b_{-m0}, \qquad (2)$$

where b_{-m0} is the initial radius of the m-th layer.

Let us examine an elementary ring of electrons with the initial radius r_0 and thickness dr_0. For such a ring, there is a charge preservation law:

$$j_z r dr dt = j_0(r_0) r_0 dr_0 dt_0.$$

According to the conditions, dt does not depend on r within the limits of each layer. Therefore, summing up all the elementary rings emerging at the same moment of time t_0 and located at the point z in the m-th layer, we obtain

$$I_m dt = i_{m0}(t_0, z) dt_0, \qquad (3)$$

where

$$I_m = 2\pi \int_{b_{-(m-1)}}^{b_{-m}} j_z r dr, \qquad r = r(z, r_0, t_0),$$

$$i_{m0}(t_0, z) = 2\pi \int_0^{b_{-N0}} \sigma_m(r) j_0(r_0) r_0 dr_0,$$

if

$$\sigma_m(r) = \begin{cases} 1, & \text{если } b_{-(m-1)} \leqslant r \leqslant b_{-m} \\ 0, & \text{в противоположном случае или при } r \geqslant b_{ст}. \end{cases}$$

in the opposite case or at

Here, b_{ct} is the radius of the walls.

The relation (3) is a corrected charge conservation law in an equivalent laminar stream. In particular, it can be seen from (3) that the equivalent laminar stream is a set of rings with variable value of the charge depending both on z, and on t_0.

The radial field created by such laminar stream can be obtained with consideration of (3) with the aid of a two-dimensional disk model of the beam [2, 3,4]:

$$E_r(r, z, t) = \sum_n \frac{I_{n0}}{2\varepsilon_0 v_0} \frac{r}{S(r, b_n)} \left\{ I_{0,n} + \operatorname{Re} \sum_k [1 - R_k(r, b_n)] I_{k,n} e^{jk\omega t} \right\},$$

where

$$S(r, b_n) = \left| \begin{array}{l} \pi r^2, \ \overset{\text{if}}{\text{если}} \ r \geqslant b_n \\ \pi b_n^2, \ \text{если} \ r \leqslant b_n, \end{array} \right. \qquad (4)$$

$$(n = 1, 2, \ldots, N, -1, -2, \ldots, -N),$$

$$b_{-(m-1)} = b_m \qquad (m = 1, 2, \ldots, N),$$

$$I_{-m0} = i_{m0} \pi b_{-m0}^2, \quad I_{m0} = -i_{m0} \pi b_{m0}^2,$$

i_{m0} is the initial density of the current in the m-th layer

$$I_{0,m}(z) = \frac{1}{2\pi} \int_0^{2\pi} \frac{i_{m0}(t_0, z)}{I_{-m0} + I_{m0}} d\omega t_0,$$

$$I_{k,m}(z) = \frac{1}{\pi} \int_0^{2\pi} \frac{i_{m0}(t_0, z)}{I_{-m0} + I_{m0}} e^{-jk\omega t_m(z, t_0)} d\omega t_0,$$

$$I_{k,-m} = I_{k,m}, \quad I_{0,-m} = I_{0,m},$$

t_m is the current time in the m-th layer.

$$R_h(r, b_n) = \frac{S(r, b_n)}{2 S_r S_{bn}} [S_r \Gamma_h(r) + S_{bn} \Gamma_k(b_n) - |S_r - S_{bn}| \Gamma_{ch}(r, b_n)],$$

$$S_r = \pi r^2, \quad S_{bn} = \pi b_n^2,$$

$$\Gamma_h(r) = \frac{S_r}{S_k^э(r)} p_k^2(r); \quad \Gamma_{ck}(r, b_n) = \frac{S_{cn}}{S_{ck}^э(r, b_n)} p_{ck}^2(r, b_n),$$

$S_{cn} = \pi |r^2 - b_n^2|$; $S_k^э(r)$, $p_h^2(r)$ is the effective cross-section area and the coefficient of the depression of the cylindrical beam with a radius r at a frequency $k\omega$; $S_{ck}^э(r, b_n)$, $p_{ck}^2(r, b_n)$ is the effective cross-section area and the depression coefficient of a hollow-ring beam (with radii r and b_n) at a frequency of $k\omega$;

$$\frac{\partial^2 t_m}{\partial z^2} = -\left(\frac{\partial t_m}{\partial z}\right)^3 \eta\{E_{zm} + F_{cm}\}, \qquad (5)$$

$$E_{zm} = \sum_{l=1}^{N} \sum_{k} \operatorname{Re} j \frac{I_0}{\varepsilon_0 k \omega S_p} \sigma^k_{ml} I_{k,l} e^{jk\omega t_m},$$

$I_0 = \sum_{n=-N}^{N} I_{n0}$ is the full current of the beam at the input; $S_p = \pi b^2_{-N0}$ is the area of the beam at the input,

$$\sigma^k_{ml} = \frac{S_p j_{l0}}{2 I_0 S_{cm}} \{-|S_{-m} - S_{-l}| \Gamma_{ck}(b_{-m}, b_{-l}) + |S_m - S_{-l}| \Gamma_{ck}(b_m, b_{-l}) +$$
$$+ |S_{-m} - S_l| \Gamma_{ck}(b_{-m}, b_l) - |S_m - S_l| \Gamma_{ck}(b_m, b_l)\},$$

$S_n = S_{bn}$; F_{cm} is the average value of the z-component of the external force on the surface of the m-th ring (depends on the type of the device: LBV [traveling-wave tube] klystron, etc); E_{zm} is the average value of the z-component of the volume-charge field on the surface of the m-th ring.

Equations (1), (2), (3), (4), (5) are the equations being sought.

In solving the system of equations (1)-(5), the main difficulty is to calculate E_{zm} because of the slow convergence of the series. In order to simplify the calculation of E_{zm}, the limit characteristic of the magnitude σ^k_{ml} was used:

$$\lim_{k\to\infty} \sigma^k_{ml} = \begin{cases} j_{m0} \dfrac{S_p}{I_0}, & \overset{\text{if}}{\text{если}}\ m = l, \\ 0, & \overset{\text{if}}{\text{если}}\ m \neq l. \end{cases} \qquad (6)$$

It follows from (6) that the slowly converging part of the series in the expression for E_{zm} consists of terms containing σ^k_{mm}; the remaining terms decrease rapidly as k increases. Separating the slowly converging part, we obtain

$$E_{zm} = -I_{cm} \int_0^{2\pi} \xi_{m1} \Delta_m (X_m)\, d\varphi_{01} + \sum_{l \neq m} \sum_{k} \operatorname{Re} j \frac{I_0}{\varepsilon_0 k \omega S_p} \sigma^k_{ml} I_{k,l}\, e^{jk\omega t_m}, \qquad (7)$$

where

$$I_{em} = I_{-m0} + I_{m0},\ X_m = \omega t_m(z, \varphi_{01}) - \omega t_m(z, \varphi_0),\ \varphi_0 = \omega t_0,\ \varphi_{01} = \omega t_{01},$$

$$\Delta_m = \sum_k \frac{1}{\pi\varepsilon_0\omega} \operatorname{Re} \frac{p_{ek}^2(b_{-m}, b_m)}{jkS_{ek}(b_{-m}, b_m)} e^{-jkX_m};\ \xi_{m1} = \frac{I_{m0}(t_{01}, z)}{I_{-m0} + I_{m0}}.$$

The first term in (7) is the proper field of the m-th layer the expression for which is known from the unidimensional nonlinear theory [5], [6]. In the remaining sum describing the mutual influence of the layers, it is possible to restrict ourselves to a finite number of terms, assuming, beginning with a certain $k > K$, $\sigma^k_{ml} \equiv 0$ $(m \neq l)$.

In (4), it is also possible to restrict ourselves to a finite number of terms in the sum with respect to k, since $R_k \to 1$ at $k \to \infty$ (in practice, it is sufficient to take 5-10 terms of the series with respect to k).

In order to evaluate the effectiveness of the "equivalent electron stream" method, computations of the dynamic defocusing in an LBV were done. In the case of $N = 1$, $M = 96$, $M_1 = 3$, the counting time of the problem decreased to one-fifth in comparison with computations done directly by the equation of a two-dimensional disk model of the beam [2] with the same number of "test" particles (with the former degree of computation accuracy).

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ELECTRONICS AND ELECTRICAL ENGINEERING

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ABSORBING-TYPE FILTER FOR A HIGH POWER LEVEL

Moscow RADIOTEKHNIKA in Russian No 1, Jan 79 pp 25-28

[Article by V. I. Vol'man and L. M. Logacheva, submitted 16 Jan 1978]

[Text] In spite of a large number of various types of waveguide filters intended for absorbing spurious radiation [1,2], there is still no filter capable of working at a high level of continuous power whose attenuation band would not have any troughs (at individual frequencies and, when the frequency of electromagnetic oscillations increases, in the area of harmonics with high numbers). Filters of the "antenna array"-type [1] have a sufficiently high electric strength, however, as the frequency increases, the attenuation in the side radiation band decreases sharply (at the frequencies of harmonics higher than the second). This is explained by the "optical beam" effect.

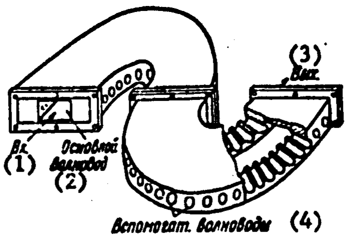

Figure 1

Key: 1. Input 3. Output
2. Main waveguide 4. Auxiliary waveguides

In order to eliminate the above-mentioned defect, a section of a rectangular waveguide uniformily bent in the plane H is used in the design of a filter described below (Figure 1). The filter consists of two identical cells connected in series each of which is a section of a uniformly bent rectangular waveguide. In order to minimize the lowering of the electric strength of the filter, the openings, which are round waveguides, are drilled in the narrow walls of the waveguide. At some distance from their inputs, part of the inner surface of the auxiliary waveguides is covered with an absorbing material, which makes it possible to accomplish effective heat removal.

In order to improve the matching of the absorbing filter, the diameters of the auxiliary waveguides decrease gradually from the center of the filter toward its ends. It is practical to select their diameters in such a way that the critical frequency f_{cr} of waveguides with the maximum diameter would be equal to 1.4-1.6 f_0 (where f_0 is the central frequency of the passband). This makes it possible to preserve small losses in the passband of the filter with a considerable attenuation in the attenuation band.

The operating principle of the filter is as follows: the power of electromagnetic oscillations within the passband passes through a regular waveguide practically without hindrance, does not branch out into the cutoff waveguides and does not suffer noticeable absorption. The bent of the structure of the filter eliminates the "optical beam" effect and therefore the inputs of the auxiliary waveguides are excited effectively at all frequencies where $f > f_{cr}$. Due to this, electromagnetic oscillations at frequencies higher than f_{cr} go into the round waveguides and their energy is dissipated in the absorbing material. A small part of energy goes into each of the cutoff waveguides, i.e., the release of thermal energy is close to uniform over the entire length of the filter.

In order to evaluate the electrical characteristics of the filter, let us determine the approximate value of the amplitude of the wave H_{11} at the inputs of the round waveguides with the aid of the method explained in [3]. Of particular interest is the interaction of this wave with the fundamental wave H_{10} of the rectangular waveguide. Since the waveguide is bent along an arc whose radius is considerably larger than the wave length ($r \gg \lambda$), the structure of the field of the fundamental wave of a uniformly bent waveguide practically does not differ from the structure of the wave H_{10} of a rectangular waveguide.

The field amplitude in the round waveguide coupled through the side wall of the rectangular waveguide, according to [3], is equal to

$$U_b = i\beta_a|M_1(\vec{H}_a^+\vec{q}_1)(\vec{H}_b\vec{q}_1) + M_2(\vec{H}_a^+\vec{q}_2)(\vec{H}_b\vec{q}_2)| + P\beta_b|\vec{E}_a^+\vec{n})(\vec{E}_b^+\vec{n}), \qquad (1)$$

for a round opening with the radius d/2; $M_1=M_2=d^3/6$ and $P=d^3/12$ are the coefficients of magnetic and electric polarization; $\vec{E}_a^+, \vec{E}_b^+, \vec{H}_a^+, \vec{H}_b$ are the normalized vectors of the intensities of electric and magnetic fields in the main waveguide (with index a) and in the coupled round waveguide (with index b); $\vec{q}_1$, $\vec{q}_2$, $\vec{n}$ are unit vectors of the rectangular system of coordinates ($\vec{q}_1$ is oriented parallel to the axis Z of the main waveguide, $\vec{n}$ of the round waveguide); d and λ_{cr} are the diameter of the round waveguide and the critical wave length of the corresponding type of wave in it; a is the size of the wide wall of the rectangular waveguide: $\beta_a = K\sqrt{1-\left(\frac{\lambda}{2a}\right)^2}$; $\beta_b = K\sqrt{1-\left(\frac{\lambda}{\lambda_{\text{кр}}}\right)^2}$.

Expressions for $\vec{E}_a^+$ and $\vec{H}_a^+$ have the following form [3]:

$$\vec{E}_a^+ = \vec{q}_2 \sqrt{\frac{2}{ab}} \sin\frac{\pi x}{a};$$
$$\vec{H}_a^+ = \sqrt{\frac{2}{ab}}\, Y_a \left(-\vec{n}\sin\frac{\pi x}{a} + \vec{q}_1 \frac{\pi}{i\beta_a}\cos\frac{\pi x}{a}\right). \qquad (2)$$

where

$$Y_a = \sqrt{\frac{\mu_0}{\varepsilon_0}} \sqrt{1-\left(\frac{\lambda}{2a}\right)^2}.$$

In computing the fields in the round waveguide, we need only expressions for the vectors of the magnetic field, because, according to (2), $(\vec{E}_a^+ \vec{n}) = 0$. Therefore

$$\vec{H}_b = \vec{q}_1 i\gamma_1 \sqrt{\frac{2}{\pi}} \frac{J_1'(\gamma_1 r)\cos\varphi}{J_1\left(\gamma_1 \frac{d}{2}\right)\sqrt{\left(\gamma_1 \frac{d}{2}\right)^2 - 1}} - \vec{\varphi}_0 \frac{1}{r}\sqrt{\frac{2}{\pi}} \times$$
$$\times \frac{J_1'(\gamma_1 r)\sin\varphi}{J_1\left(\gamma_1 \frac{d}{2}\right)\sqrt{\left(\gamma_1 \frac{d}{2}\right)^2 - 1}}. \qquad (3)$$

where $\gamma_1 = 2\pi/\lambda_{cr}$ and r represent the current values of the radius. Substituting expressions (2) and (3) in (1), we obtain

$$U_b = \frac{\sqrt{\pi}}{6} A \frac{\beta_b}{\beta_a} \frac{\gamma_1 d^2}{a\sqrt{ab}} \frac{1}{J_1(\gamma_1 r)\sqrt{(\gamma_1 r)^2 - 1}}. \qquad (4)$$

where A is the amplitude of the intensity of the electric field of the wave in the rectangular waveguide.

The power propagating in the rectangular waveguide is equal to

$$P_0 = \frac{1}{2} Y_a A^2, \qquad (5)$$

and the power at the input of the round waveguide is

$$P_b = \frac{1}{2} U_b^2 Y_b. \qquad (6)$$

Consequently

$$\frac{P_b}{P_a} = \left(\frac{U_b}{A}\right)^2 \frac{Y_b}{Y_a}. \qquad (7)$$

where

$$Y_b = \sqrt{\frac{\mu_0}{\varepsilon_0}} \sqrt{1-\left(\frac{\lambda}{\lambda_{\text{кр}}}\right)^2}\underset{(1)}{}.$$

Key: 1. critical

Substituting (4) in (7), we find

$$\frac{P_b}{P_0} = \frac{\pi}{9} \frac{(\gamma_1 d/2)^2}{J_1^2(\gamma_1 d/2)\,|(\gamma_1 d/2)^2-1|} \left(\sqrt{\frac{1-(\lambda/\lambda_{\text{кр}})^2}{1-(\lambda/2a)^2}}\right)^3 \frac{d^4}{a^3 b}. \tag{8}$$

For the wave H_{11}, $\gamma_1 d/2=1.84$, therefore,

$$\frac{P_b}{P_0} = \frac{3d^4}{2a^3 b} \left(\sqrt{\frac{1-(\lambda/\lambda_{\text{кр}})^2}{1-(\lambda/2a)^2}}\right)^3. \tag{9}$$

In the case of a standard waveguide, when b = a/2,

$$\frac{P_b}{P_0} = 3\left(\frac{d}{a}\right)^4 \left(\sqrt{\frac{1-(\lambda/\lambda_{\text{кр}})^2}{1-(\lambda/2a)^2}}\right)^3. \tag{10}$$

Let us determine the losses in the passband of the filter caused by the penetration of electromagnetic oscillations into the cutoff waveguides. If the absorbing loads in the cutoff waveguides are located at the distance l from their beginning, then the power at the input of the absorbing load is equal to $P(l) = P_b e^{-2|\beta_b|l}$. With allowance made for this equality, the losses per one opening of the maximum diameter will be equal to

$$\frac{P_b}{P_0} = 3\left(\frac{d}{a}\right)^4 \left(\sqrt{\frac{1-(\lambda/\lambda_{\text{кр}})^2}{1-(\lambda/2a)^2}}\right)^3 e^{-2|\beta_b|l}. \tag{11}$$

The value of the losses calculated by (11) is somewhat overestimated, because, in deriving it, it was assumed that the fields exciting the round waveguides at any point of the input plane of the round waveguide were cophasal. If we consider that they are not cophasal, the obtained value has to be multiplied by $\left(\frac{\sin \beta_a d/2}{\beta_a d/2}\right)^2$.

Let us now determine the losses introduced by the filter in the attenuation band. When the condition $\lambda \ll \lambda_{cr}$ is fulfilled, the losses of a filter with N openings for the wave H_{11}, from expression (10), are equal to

$$N\frac{P_b}{P_0}=3\left(\frac{d}{a}\right)^4 N.$$

Then the losses introduced by the filter in the attenuation band in the general case will be

$$B=10\lg CN\left(\frac{d}{a}\right)^4,\ \text{дБ, dB} \qquad (12)$$

where $C=\frac{2\pi}{\psi}\frac{1}{J_1^2\left(\gamma_1\frac{d}{2}\right)\left[\left(\gamma_1\frac{d}{2}\right)^2-1\right]}$, which follows from (8).

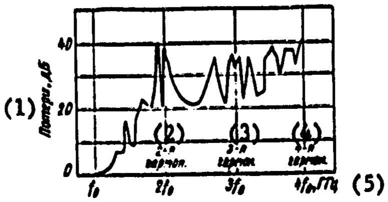

Figure 2

Key:
1. Losses, dB
2. Second harmonic
3. Third harmonic
4. Fourth harmonic
5. GHz

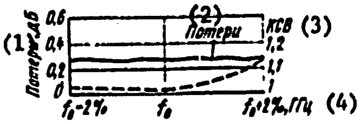

Figure 2.

Key:
1. Losses, dB
2. Losses
3. KSV [standing-wave ratio]
4. GHz

Figure 4.

Key:
1. KSV
2. GHz

In addition to the wave of the main type H_{11}, oscillations of other higher types can propagate at sufficiently high frequencies in round waveguides. Calculations have shown that the coefficient C increases as the wave number increases, which indicates an increase in the attenuation introduced by the filter as the frequency grows.

The selected dimensions of the main waveguide of the experimentally studied absorbing filter consisting of two cells of the described type connected in series were standard. Figure 2 shows the dependence of attenuation introduced by the filter on the frequency: the filter ensures losses of not less than 35 dB in the band from the second to the fourth harmonic, inclusively, and the attenuation increases steadily as the frequency increases, the calculated value of the losses introduced by the filter is 38 dB, which is well in agreement with the experimental data. The losses of the filter in the transmission frequency band did not exceed 0.3 dB (Figure 3), while the KSV was 1.01-1.02.

The total losses connected with the losses in the cutoff waveguides calculated by (11) were 0.1 dB for 38 auxiliary waveguides. Figure 4 shows the dependence of the KSV on the frequency in a range of up to the third harmonic.

The advantanges of the proposed filter are: a good matching and small losses in the operating frequency range, as well as a good matching and a sufficiently great attenuation at the harmonic frequencies. The filter has a simple design and acceptable size and weight.

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ELECTRONICS AND ELECTRICAL ENGINEERING

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SYNTHESIS OF CIRCUITS AND SIGNALS FOR PARAMETRICALLY INVARIANT RECEIVING DEVICES

Moscow RADIOTEKHNIKA in Russian No 1, Jan 79 pp 33-38

[Article by D. V. Kruchinin, submitted 24 May 1978]

[Text] In systems for improving traffic safety, radio engineering systems with complicated signals are used for spatial selection of radio signals reflected from interfering objects. The receiving device in such systems must form a prescribed dependence $\rho(\tau)$ of the informational parameter of the output signal on the distance to these objects, or the delay τ of the expected signal uniquely connected with it. The $\rho(\tau)$ dependence is characterized by a considerable lowering of the value of the informational parameter outside the monitored delay range $\tau \in |\tau_1, \tau_2|$.

Statement of the Problem. It is known [1] that the predetection part of sensitive receivers of complex signals can be designed on the basis of follow-up radio engineering devices with variable parameters. However, they have some disadvantages: the necessity of the expenditure of time on searching for the expected signal and the possibility of tracking failure. This article examines the method of using nonsynchronized linear circuits with variable parameters (LTsPP) which is free from these disadvantages.

One of the problems on which researchers are working is the creation of LTsPP, invariant $\tau \in |\tau_1, \tau_2|$, or parametrically invariant LTsPP. The possibility of its positive solution follows from the results of the analysis of LTsPP [1]: the dependence of the informational parameters of the output signal of such circuits on the delay of the complex input signal in a certain range τ is expressed weakly. But the form of this dependence may not correspond to what is prescribed, therefore, the searching for the necessary structure of such circuits must be solved through synthesis. The proposed method consists of the synthesis of the form of the expected signal and the pulse characteristic of a parametrically invariant LTsPP, as well as through its schematic realization and the algorithm of the operation of the device for forming the transmitted signal. The procedure of the schematic realization coincides with the procedure described in [3], therefore, only the first part of the proposed method is discussed here.

Let us assume that an additive mixture x of an interference p and the expected signal acts at the input of the initial noninvariant receiver:

$$S_н(\xi,\tau)=C\sum_{k=-n}^{N} R_k\Psi_k(\xi,\tau), \qquad (1)$$

where N, n, C, R_k are constant values; ξ is the current time; $\Psi_k(\xi,\tau)$ is the function of ξ and τ .

The predetection part of the receiver is an LTsPP matched by the criterion of [2] with the signal (1) at $\tau=\tau_0$. Its pulse characteristic is:

$$G_н(l,\xi,\tau_0)=\sum_{k=-n}^{N} R_k\Phi_k(l,\tau_0)\Psi_k(\xi,\tau_0), \qquad (2)$$

where $\Phi_k(l,\tau_0)$ is the function of the observation time l; $N+n+1=\sum_{s=1}^{v} u_s$; v is the number of channels (if the LTsPP is multichannelled); u_x is the order of the circuit entering the x-channel.

The condition of parametric invariance of the LTsPP to $\tau\in[\tau_1,\tau_2]$ is defined by the relation

$$p(\tau)M[y_н(l,\tau_0)]=M[y_c(l,\tau)], \qquad (3)$$

where $y_н$ is the output signal of the initial noninvariant circuit; y_c is the output signal of the LTsPP with the pulse characteristic $G_c(t,\xi)$ which is being sought; M is the operator of the calculation of the informational parameter of signals $y_н$ and y_c realized by the functional units of the receiver which follow its linear part. Functions $M[y_н(l,\tau_0)]$, $M[y_c(l,\tau)]$, p, $G_н(l,\xi,\tau_0)$, $G_c(l,\xi)$, $\Phi_k(l,\tau_0)$, $\Psi_k(\xi,\tau)$, $p(\tau)$, $S_c(\xi,\tau)$ (the expected signal being sought) and $S_н(\xi,\tau)$ belong to the space L_2 of square integrable functions.

With the above assumptions, it is required to determine $G_c(t,\xi)$ and $S_c(\xi,\tau)$ satisfying the condition (3) without changing M. For the sake of simplicity, the interference p is not taken into consideration in the process of synthesizing $G_c(t,\xi)$, $S_c(\xi,\tau)$. The stability of the synthesized LTsPP to it is evaluated during subsequent analysis.

Method of Synthesis. We shall obtain the solution of the problem by correcting $S_н$, $G_н$, for which we shall represent (1) and (2) in the following form:

$$G_н(l,\xi,\tau_0)=\sum_{l=-\lambda}^{L} b_l Q_l(\tau_0)\varphi_l(l)r_l(\xi); \qquad (4)$$

$$S_{\text{н}}(\xi,\tau)=C\sum_{l=-\lambda}^{L} d_l H_l(\tau) r_l(\xi), \qquad (5)$$

where $Q_l(\tau_0)$, $H_l(\tau)$, $\varphi_l(l)$, $r_l(\xi)$ are functions forming complete systems of functions in the space L_2; b_l, d_l are the coefficients of the expansion of functions (1) and (2) in series.

We seek expressions for S_c, G_c in the form of series by the same systems of functions

$$G_c(l,\xi)=\sum_{l=-\lambda}^{L} w_l \varphi_l(l) r_l(\xi); \qquad (6)$$

$$S_c(\xi,\tau)=C\sum_{l=-\lambda}^{L} W_l H_l(\tau) r_l(\xi), \qquad (7)$$

where w_l, W_l are the coefficients to be defined.

On the basis of (4)-(7) and [4], we shall write the expressions for $y_{\text{н}}$ and y_c. Having substituted them in (3), we find the equation for calculating w_l and W_l :

$$\begin{gathered}\rho(\tau)M\left[\int_0^l C\sum_{l=-\lambda}^{L} d_l H_l(\tau) r_l(\xi)\sum_{l=-\lambda}^{L} b_l Q_l(\tau_0)\varphi_l(l) r_l(\xi)\,d\xi\right]=\\ =M\left[\int_0^l C\sum_{l=-\lambda}^{L} W_l H_l(\tau) r_l(\xi)\sum_{l=-\lambda}^{L} w_l\varphi_l(l) r_l(\xi)\,d\xi\right].\end{gathered} \qquad (8)$$

Solution of (8) gives the values of w_l, W_l which were sought. After their substitution in (6), (7), this stage of LTsPP synthesis and signal selection ends.

As can be seen, (8) belongs to the class of indeterminate equations whose theory remains practically undeveloped. In special cases, additional conditions are introduced for their solution. Let us illustrate the application of the proposed method on a concrete example.

Example. Let us assume that the transmitter and the receiver satisfy the following conditions

$$S_{\text{н}}(\xi,\tau)=C\sum_{k=-n}^{N} R_k \sin\{\omega_0(\xi-\tau)+\gamma_0+k[\Omega(\xi-\tau)+\theta_0]\}, \qquad (9)$$

where ω_0 is the carrier frequency; Ω is the modulation frequency; C is the amplitude; θ_0, R_k, γ_0 are the parameters which do not depend on ξ and τ. Signal (9) is present at the input of the linear part of the initial receiver -- noninvariant ЛТвРР [see Figure 1, where П is the mixer (multiplier), Г is the heterodyne, УПЧ is the resonance intermediate frequency amplifier with a single-circuit concentrated-selection filter].

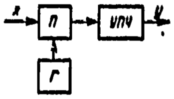

Figure 1

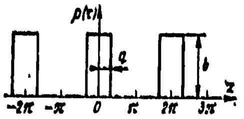

Figure 2

The pulse characteristic of this circuit is:

$$G_{н}(t, \xi, \tau_0) = \Gamma_{н}(\xi, \tau_0) \exp[\alpha(\xi - t)] \sin[\omega_{пр}(t - \xi) + \gamma]. \quad (10)$$

where α represents the losses in the УПЧ circuit; $\omega_{пр} = \omega_c - \omega$ is the intermediate frequency;

$$\Gamma_{н}(\xi, \tau_0) = A \sum_{k=-n}^{N} R_k \sin\{\omega(\xi - \tau_0) + \gamma_0 + k[\Omega(\xi - \tau_0) + \theta_0]\}, \quad (11)$$

is the function describing the oscillation formed by the heterodyne; ω and A are its carrier frequency and amplitude.

The informational parameters of the signals $y_{н}$ and y_c are their amplitudes. The required dependence of the amplitude of y_c on τ is described by the function $\rho(\tau)$ which is represented graphically in Figure 2, where

$$z = \theta_0 - \theta - \Omega\tau; \quad b = \left(\sum_{k=-n}^{N} R_k^2\right)^{-1}; \quad \tau_1 = -\infty; \quad \tau_2 = \infty. \quad (12)$$

In accordance of the above procedure, we search for $S_c(\xi, \tau)$ and $G_c(t, \xi)$ in the form of

$$S_c(\xi, \tau) = C \sum_{l=-\lambda}^{L} W_l \sin\{\omega_0(\xi - \tau) + \gamma_0 + l[\Omega(\xi - \tau) + \theta_0]\}; \quad (13)$$

$$G_c(t, \xi) = \Gamma_c(\xi) \exp[\alpha(\xi - t)] \sin[\omega_{пр}(t - \xi) + \gamma], \quad (14)$$

where

$$\Gamma_c(\xi) = A \sum_{l=-\lambda}^{L} w_l \sin[\omega\xi + l(\Omega\xi + \theta)] \quad (15)$$

is the function describing the corrected oscillation of the heterodyne; θ is a constant.

Assuming that the initial conditions are zero conditions, $a \ll \omega \gg 1$, t is large, and $\omega \pm \omega_0 + l\Omega \neq \omega_{np}$, we determine the amplitudes of y_H and y_c. Substituting them in (3), we shall obtain an equation for

$$\rho(\tau)\frac{AC}{4a}\sum_{k=-n}^{N} R_k^2 = \frac{AC}{4a}\left(\left\{\sum_{l=-\lambda}^{L} w_l W_l \sin[l(\theta_0-\theta-\Omega\tau)]\right\}^2 + \right.$$
$$\left. + \left\{\sum_{l=-\lambda}^{L} w_l W_l \cos[l(\theta_0-\theta-\Omega\tau)]\right\}^2\right)^{\frac{1}{2}}. \tag{16}$$

We solve equation (16) in two stages: first we calculate the product $w_l W_l$, and then w_l and W_l, imposing additional conditions. In order to calculate $w_l W_l$, let us use the representation of $\rho(\tau)$ (Figure 2) in the form of

$$\rho(\tau) = b\sum_{l=-\infty}^{\infty} \beta_l \cos[l(\theta_0-\theta-\Omega\tau)], \tag{17}$$

where $\beta_l = [\sin(lg)]/l\pi$. The condition (16) is satisfied at $L = \lambda = \infty$ and $w_l W_l = \beta_l$.

Now let us examine two variants of additional conditions: 1) all w_l are equal to W_l; 2) w_l may not be equal to W_l, but are uniquely coupled with them. The second variant includes also the simplest case when one group of the coefficients $\{w_l\}$ or $\{W_l\}$ is given.

Let us assume that the first additional condition is introduced, when the matching with respect to form for $S_c(\xi)$ and $\Gamma_c(\xi)$ is accomplished. This will make it possible to receive $S_c(\xi)$ with minimal losses in the stability against interference of the type of "white noise" in comparison with an optimal receiver. Then

$$w_l = W_l = \pm\sqrt{\beta_l}. \tag{18}$$

Having substituted (18) in (13)-(15), we shall obtain

$$S_c(\xi,\tau) = C\sum_{l=-\infty}^{\infty}[\pm\sqrt{\beta_l}]\sin(\omega_0(\xi-\tau)+\gamma_0+l[\Omega(\xi-\tau)+\theta_0]); \tag{19}$$

$$G_c(t,\xi) = \Gamma_c(\xi)\exp[\alpha(\xi-t)]\sin[\omega_{np}(t-\xi)+\gamma], \tag{20}$$

where

$$\Gamma_c(\xi) = A\sum_{l=-\infty}^{\infty} W_l \sin[\omega\xi + l(\Omega\xi+\theta)]. \tag{21}$$

The obtained functions (19)-(21) are not realized physically in the general case, because at $\beta_l < 0$, according to (17), the coefficients w_l, W_l must be imaginary. Therefore, let us examine the other variant of additional conditions according to which deviation from (18) is permissible. Let us assume that w_l and W_l are connected by the following relations:

$$w_l W_l = \beta_l, \quad W_l = \pm \sqrt{|\beta_l|}. \tag{22}$$

Then,

$$S_c(\xi, \tau) = C \sum_{l=-\infty}^{\infty} W_l \sin[\omega_0(\xi - \tau) + \gamma_0 + l[\Omega(\xi - \tau) + \theta_0]]; \tag{23}$$

$$G_c(t, \xi) = \Gamma_c(\xi) \exp[a(\xi - t)] \sin[\omega_{\text{пр}}(t - \xi) + \gamma], \tag{24}$$

where

$$\Gamma_c(\xi) = A \sum_{l=-\infty}^{\infty} \frac{\beta_l}{W_l} \sin[\omega\xi + l(\Omega\xi + \theta)];$$

w_l and W_l are real numbers [according to (22)] which are equal in modulus, but may differ in sign if not all $\beta_l > 0$. As can be easily seen, the same formulas will be obtained if W_l are given.

It follows from comparison of (10) with (20) and (24) that, in order to transform a noninvariant LTsPP into a parametrically invariant LTsPP, it is sufficient in this case to correct the mode of the expected signal and the oscillation mode of the heterodyne.

Calculations have shown that the problem of signal selection and synthesis of the pulse characteristic of a parametrically invariant LTsPP by correcting the initial noninvariant circuit and the initial signal can, in principle, be solved by the proposed method. But the influence of the interference p is not taken into consideration in this case. Therefore, let us analyze the interrelation of parametric invariance of LTsPP with the stability of their work in the presence of an interference.

Analysis of Noise Stability of a Parametrically Invariant LTsPP. Let us assume that an interference p of the "white noise"-type is present at the input of an LTsPP with pulse characteristic (24) mixed with signal (23). In order to evaluate the influence of this interference, let us compare the values of the signal/noise ratios at the output of a parametrically invariant receiver and a noninvariant receiver, assuming in (9), (11), (12) $R_k = W_l$. On the basis of [4], for an LTsPP with pulse characteristics (10), (14) in the presence of signals (9), (13) at the input, we have, respectively,

$$\frac{P_{\text{к}}}{\sigma^2_{\text{шк}}} = \frac{C^2}{aN_0 b} = \frac{E_s}{taN_0}; \tag{25}$$

$$\frac{P_c}{\sigma^2_{шc}} = \frac{C^2\rho^2(\tau)}{aN_0b^2}\Big(\sum_{l=-\infty}^{\infty} w_l^2\Big)^{-1} = \frac{E_s}{taN_0}\,\frac{\rho^2(\tau)}{b}\Big(\sum_{l=-\infty}^{\infty} w_l^2\Big)^{-1}. \tag{26}$$

where $P_{м}$, P_c represent the power of signals at the output of the circuits under consideration; E_s is the energy of the expected signal; N_0 is the spectral density of p; $\sigma^2_{шм}$ and $\sigma^2_{шc}$ represent noise dispersion at the outputs of LTsPP with characteristics (10) and (14). Expression (26) differs from (25) by the factor

$$\delta = \frac{\rho^2(\tau)}{b}\cdot\Big(\sum_{l=-\infty}^{\infty} w_l^2\Big)^{(-1)},$$

which depends on τ and is different from zero at $z \in [2l\pi + q,\ 2l\pi - q]$ (Figure 2). For such z, taking into consideration (12), (17), (20) and using the Bunyakovskiy-Cauchy inequality, we obtain

$$\delta = \Big(\sum_{l=-\infty}^{\infty} W_l^2\Big)^{(-1)}\Big(\sum_{l=-\infty}^{\infty} w_l^2\Big)^{(-1)} \leq \Big(\sum_{l=-\infty}^{\infty} W_l w_l\Big)^{(-2)} = \Big(\sum_{l=-\infty}^{\infty} \beta_l\Big)^{(-2)} = 1. \tag{27}$$

Equality in (27) is achieved when $W_l = w_l$, which (as has been shown above) cannot always be physically realized. Consequently, the obtaining of parametric invariance could entail a loss in the noise stability of the LTsPP. Let us estimate the upper bound of the possible values of these losses $\hat{\delta}$, if w_l, W_l are calculated by (22). To do this, let us approximate $\pi|\beta_l|lq$ by a stepped line (Figure 3) and use the expression $\rho(\tau)$ in the form of a truncated series. The estimate $\hat{\Delta}$ of the remainder of this alternating series which does not exceed the level of the first dropped step of the approximating line characterizes the accuracy of the fulfillment of condition (3). Then, for the accepted z, regardless of q,

$$\hat{\delta} < \Big(2 + \frac{4}{\pi}\sum_{\mu=1}^{m}\frac{1}{2\mu+1}\Big)^{-2}; \quad (28) \qquad \hat{\Delta} < \frac{2}{\pi}\,\frac{1}{2m+1}. \quad (29)$$

where μ is the number of the step of the approximating line (Figure 3) at $lq \geqslant \pm\pi$. The dependence of the estimate $\hat{\delta}$ on $\hat{\Delta}$ (Figure 4) which shows the connection of the accuracy of the fulfillment of the condition of parametric invariance of the LTsPP with its stability against noise was calculated by (28) and (29). As can be seen, as $\hat{\Delta}$ decreases, the losses in the stability against noise increase, and, as the permissible $\hat{\Delta}$ increases, they decrease. If $\hat{\Delta} > 21.2\%$ is permissible, then, in (22), it is necessary to substitute $\beta_l = \sin(lq)/l\pi$, where $lq \in [-\pi, \pi]$. With such arguments $\beta_l \geqslant 0$, coefficients w_l and W_l can be equal to $\pm\sqrt{\beta_l}$ and the losses in the noise stability of a parametrically invariant LTsPP are minimal.

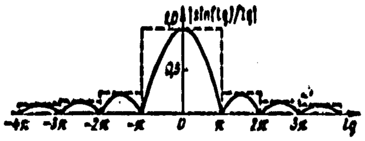

Figure 3

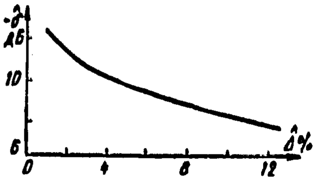

Figure 4

Thus, the method examined above makes it possible to synthesize a parametrically invariant LTsPP. Invariance is achieved at the cost of losses in noise stability which increase as the required accuracy of the fulfillment of the condition of parametric invariance increases.

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ELECTRONICS AND ELECTRICAL ENGINEERING

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CORRELATION FUNCTION AND AVERAGED POWER OF RADAR SIGNAL REFLECTED FROM AN AGITATED SEA SURFACE

Moscow RADIOTEKHNIKA in Russian No 1, Jan 79 pp 85-88

[Article by A. I. Baskakov, submitted after revision 12 Jan 1978]

[Text] Data on the degree of agitation of a sea surface can be obtained by using the radar method of vertical sounding [1]. Let us write a pulse signal of the microwave band radiated by an RLS [radar station] as

$$S(t)=\mathrm{Re}\{\sqrt{2P_0}\,\dot{U}(t)\exp(i\omega_0 t)\}, \qquad (1)$$

where $\dot{U}(t)=U_a(t)\exp[i\psi(t)]$ is the complex law of modulation. Let us use a phenomenological model of a sea surface [2] which is a set of independent elementary reflectors. The reflected signal is a superposition of partial signals over the irradiated area which have random, independent phases evenly distributed in the interval of $0\div 2\pi$. Let us assume that the receiver of the RLS consists of a filter matched with the sounding signal and an envelope detector. The signal at the filter output

$$u(t)=\mathrm{Re}\left\{\sum_{n=1}^{N}k_\Phi\sqrt{\frac{2P_0\lambda^2G_0^2\sigma_n}{(4\pi)^3}}\,F(\theta_n,\varphi_n,t)\frac{\dot{\rho}\left(t-\frac{2R_n}{c}-t_\Phi\right)}{R_n^2(\theta_n,\varphi_n,t)}\times\right.$$
$$\left.\times\exp\left[i\left(\omega_0+\omega_{g_n}\right)\left(t-\frac{2R_n}{c}-t_\Phi\right)\right]\right\}, \qquad (2)$$

where P_0 is the radiation power; λ is the radio-wave length; G_0 is the antenna gain (the transmitting and the receiving antennas are combined); σ_n is the effective reflection area of an elementary reflector normally oriented toward the direction of incidence of radio waves considered as an average of the set of values of effective reflection areas of elementary reflectors, and, since the surface is uniform, it can be considered without loss of generality that σ_n is identical for all reflectors [2]; θ_n, φ_n are the coordinates of the n-th reflector; c is the speed of light; $F(\theta_n, \varphi_n, t)$ is the normalized coefficient determined by the antenna pattern (DNA) and the back scattering pattern of the surface (DOR); $R_n(\theta_n, \varphi_n, t)$ is the distance from the RLS to the n-th reflector; ρ (t) is the autocorrelation function of the sounding signal; ω_{gn} is the Doppler frequency shift. In order to simplify the operations, the transfer factor of the filter $k_ф$ and the delay $t_ф$ will be assumed to be, respectively, $k_ф = 1$, $t_ф = 0$. The dependence of the reflected signal on the Doppler frequency and the dependence of $F(\theta, \varphi, t)$, $R(\theta, \varphi, t)$ on the time can be disregarded, because, in practice, the relation $vT_и \sin\theta \leq \lambda/4$, where v -- RLS speed, $T_и$ -- length of the sounding pulse ($T_и \leq 10^{-7}$c) is always fulfilled. We shall assume that the 0.5-power width does not exceed $\theta_0 \leq 30°$, and the axis is oriented in the vicinity of a perpendicular to the XOY plane. Consequently, the surface can be considered "frozen" for the high-frequency phase during the time $T_и$. The geometry of the problem is shown in Figure 1.

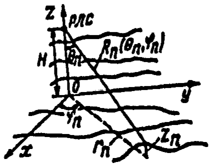

Figure 1

The echo signal is characterized by its autocorrelation function:

$$\dot{R}(t_1, t_2) = \mathrm{Re}\left\{\frac{2P_0\lambda^2G_0^2}{(4\pi)^3} M\left[\sum_{n=1}^{N}\frac{\sigma_n F^2\,\theta_n, \varphi_n}{R_n^4(\theta_n, \varphi_n)}\,\dot{\rho}(t_1-\tau_n)\overset{*}{\rho}(t_2-\tau_n)e^{i\omega_d(t_1-t_2)}\right]\right\}. \tag{3}$$

where

$$\frac{2R_n}{c} \approx \tau_0 + \frac{r_n^2}{cH} + \eta_n; \quad \tau_0 = \frac{2H}{c}; \quad \eta_n = -\frac{2Z_n}{c}; \quad H \gg r.$$

When calculating the statistical characteristics, it is practical to switch from summation to integration [2]. The averaging in (3) is done by a set of random reflectors arranged along the ordinate z with the probability density P(z) described by the normal distribution law [3] with the root-mean-square ordinate $\sigma_z \gg \lambda$:

$$R(t_1, t_2) = \mathrm{Re}\left\{\frac{2P_0\lambda^2G_0^2\sigma_0}{(4\pi)^3}\int_S \frac{F^4(\theta, \varphi)}{R^4(\theta, \varphi)} e^{i\omega_d(t_1-t_2)}\int_{-\infty}^{\infty} P(\eta)\dot{\rho}(t_1-T-\eta)\times\right.$$
$$\left.\times\overset{*}{\rho}(t_2-T-\eta)\,d\eta\,dS\right\}, \tag{4}$$

where $T = \tau_0 + \frac{r^2}{cH}$; σ_0 is the specific effective area of reflection for a wave falling normally; $K_0^2/a_{\text{ш}}^2$; K_0 is the Fresnel coefficient; $a^2_{\text{ш}}$ is the roughness parameter [2]. Let us use θ_s to denote the angle of the deflection of the DNA axis from the normal to the average level of the surface, and use α to denote the angle read from the DNA axis. The DNA axis is projected on the coordinate axis X, and the angle φ is read from axis X. For small α, θ and θ_s,

$$\alpha^2 \approx \theta_S^2 - 2\theta\theta_S \cdot \cos\varphi + \theta^2. \tag{5}$$

We shall take the expression for DOR from [2]; then, with consideration for (5), we shall obtain

$$F^2(\theta,\varphi) = \exp\left(-\frac{\mathrm{tg}^2\theta}{a_{\text{ш}}^2}\right)\exp\left(-5{,}55\frac{\theta_S^2}{\theta_0^2} + 11{,}1\frac{\theta\theta_S\cos\varphi}{\theta_0^2} - 5{,}55\frac{\theta^2}{\theta_0^2}\right). \tag{6}$$

In (4), let us go over to polar coordinates and integrate with respect to φ:

$$\begin{gathered}R(t_1+\tau_0;\, t_2+\tau_0) = \mathrm{Re}\left\{\frac{2\pi P_1}{H^4}\exp\left(-5{,}55\frac{\theta_S^2}{\theta_0^2}\right)\exp[i\omega_0(t_1-t_2)]\times\right.\\ \times\int_0^\infty \exp\left(-\frac{r^2}{\psi^2H^2}\right) I_0\left(\frac{11{,}1\theta_S r}{\theta_0^2 H}\right)\left[\int_{-\infty}^{\infty} P(\eta)\dot{\rho}\left(t_1-\frac{r^2}{cH}-\eta\right)\times\right.\\ \left.\left.\times\, \overset{*}{\dot{\rho}}\left(t_2-\frac{r^2}{cH}-\eta\right)d\eta\right] r\,dr\right\}.\end{gathered} \tag{7}$$

Having assumed that $t_1 = t_2$, we shall find the expression for the average power of the signal characterizing the averaged shape of a pulse reflected from a sea surface:

$$\begin{gathered}P(t+\tau_0) = \frac{2\pi P_1}{H^4}\exp\left(-5{,}55\frac{\theta_S^2}{\theta_0^2}\right)\int_0^\infty \exp\left(-\frac{r^2}{\psi^2H^2}\right) I_0\left(\frac{11{,}1\theta_S r}{\theta_0^2 H}\right)\times\\ \times\int_{-\infty}^{\infty} P(\eta)\left|\dot{\rho}\left(t-\frac{r^2}{cH}-\eta\right)\right|^2 d\eta\, dr,\end{gathered} \tag{8}$$

where $P = 2P_0\lambda^2G_0^2\sigma_0/(4\pi)^3$; $\psi^2 = \theta_0^2 a_{\text{ш}}^2/(5{,}55a_{\text{ш}}^2 + \theta_0^2)$; $I_0(\cdot)$ is a zero-order Bessel function of an imaginary argument.

For example, let us assume that a short Gaussian radio pulse is emitted, where $U(t) = e^{-\beta^2t^2}$ is the pulse length at a level of 0.46. It can be easily shown that

$$\rho(\tau)=\frac{1}{\sqrt{2}}\exp\left(-\frac{g^2\tau^2}{2}\right). \tag{9}$$

Let us use the following approximation:

$$I_0(x)=\exp(x^2/4), \quad x<1. \tag{10}$$

Having substituted (9), (10) in (8), gone over to the variable $\gamma = r^2/cH$, and substituting $t_1 = \tau_0 = t$; $t_2 + \tau_0 = t + \tau$, we shall obtain:

$$R(t;\,t+\tau)=\mathrm{Re}\left\{\frac{P_0\lambda^2G_0^2\sigma_0 c}{64\pi^{3/2}H^2g}\exp\left(-5{,}55\frac{\theta_S^2}{\theta_0^2}\right)\exp\left\{\frac{b^2[1+(g\tau)^2]}{2g^2}-\frac{\left(\tau+\frac{b}{g^2}\right)^2g^2}{4}-\right.\right.$$
$$\left.\left.-bt\right\}\left[\frac{1}{2}-\Phi\left(\frac{b\sqrt{1+2(g\tau)^2}}{2g}-\frac{(2t+\tau)g}{2\sqrt{1+2(g\tau)^2}}\right)\right]\exp(-i\omega_0\tau)\right\}; \tag{11}$$

$$P(t)=\frac{P_0\lambda^2G_0^2\sigma_0 cT_{\text{и}}}{64\pi^2H^2}\exp\left(-5{,}55\frac{\theta_S^2}{\theta_0^2}\right)\exp\left(\frac{b^2\mu^2}{4}-bt\right)\left[\frac{1}{2}-\Phi\left(\frac{b\mu}{2}-\frac{t}{\mu}\right)\right]. \tag{12}$$

where

$$b=\frac{c}{HB^2_{\text{экв}}};\quad B^2_{\text{экв}}=\frac{a^2_{\text{ш}}\theta_0^2}{5{,}55a^2_{\text{ш}}\left(1-5{,}55\theta_S^2/\theta_0^2\right)+\theta_0^2};$$

$$\mu=\sqrt{\frac{T^2_{\text{и}}}{\pi}+2a^2};\quad a=\frac{2\sigma_z}{c};\quad \Phi(x)=\frac{1}{\sqrt{\pi}}\int_0^x e^{-y^2}\,dy.$$

The presence of the factor $\left(-5{,}55\frac{\theta_S^2}{\theta_0^2}\right)$ in (12) characterizes the decrease in the power of the reflected signal as the angle θ_S increases. With allowance made for (10) formulas (11) and (12) are true for angles $\theta_S \leqslant \theta_0/5.55$. If we limit ourselves to the zone irradiated on the surface which is essential for the formation of the leading edge of the reflected pulse, $r_{\text{и}} \approx \sqrt{cT_{\text{и}}H} < H\,\mathrm{tg}\frac{\theta_0}{2}$, then (12) describes its shape correctly at angles $\theta_S < \theta_0^2/5.55\theta_{\Phi p}$; $\theta_{\Phi p} = 2\,\mathrm{arctg}\sqrt{cT_{\text{и}}/H}$. Calculations on a digital computer for a normalized pulse shape

$$P_u(t) = \exp\left(\frac{b^2\mu^2}{4} - bt\right)\left[\frac{1}{2} - \Phi\left(\frac{b\mu}{2} - \frac{t}{\mu}\right)\right]$$

for the following values of the parameters: 1) $T_u = 2\cdot10^{-9}$ c; $b = 2,12\cdot10^{8}$ Hz; $\theta_S = 0$; $\sigma_\xi = 1 \div 4$ м; 2) $T_u = 2\cdot10^{-9}$ c; $\theta_0 = 17°$; $H = 10$ км; $\alpha^2_{ш} = 0,16$; $\sigma_\xi \sim 1$ м; $\theta_S = 0,\ 1°, 2°, 3°, 4°$ are shown in Figures 2 and 3. It follows from the analysis of (12) and Figures 2 and 3 that:

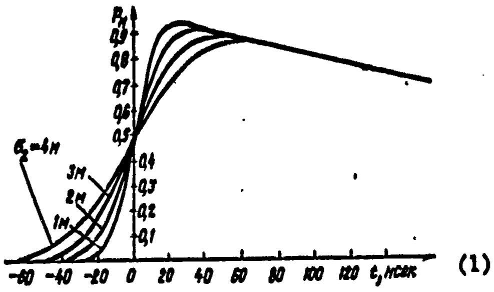

Figure 2
Key: 1. nsec

1. An essential peculiarity of the averaged shape of a signal reflected from the sea is its sensitivity to the agitated state of the sea surface.

2. In order to achieve a high degree of sensitivity to weak agitation, it is necessary to have sounding pulses with a duration of a few nanoseconds.

3. When working with a wide DNA of an RLS $\theta_0 \gg 2\sqrt{cT_u/H}$, the height of sea waves can be estimated by the shape of the leading edge of the averaged reflected pulse. For the same wind force, the shape of the leading edge does not change significantly when the DNA axis deflects from the normal to the average level of the surface up to $\theta_S \approx 0.25\ \theta_0$.

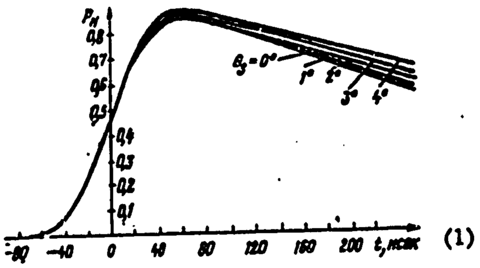

Figure 3
Key: 1. nsec

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ELECTRONICS AND ELECTRICAL ENGINEERING

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ACOUSTIC-OPTICAL PROCESSING OF THE WIDEBAND SIGNALS OF TWO-DIMENSIONAL PHASED ANTENNA ARRAYS

Kiev IVUZ RADIOELEKTRONIKA in Russian Vol 22 No 2, Feb 79 pp 76-79

[Article by G.S. Nakhmanson and V.M. Yanyshev, manuscript received 10 Apr 76]

[Text] A considerable interest is being observed at the present time in radar and sonar in the application of optical methods of processing signals received by phased antenna arrays (FAR), where this interest is generated by well-known merits of coherent optical information processing [1]. Acoustic-optical processing is numbered among such methods in which multichannel, untrasonic light modulators (UZMS) serve as the input devices, where these modulators allow for signal processing in real time. The processing of narrow band phased antenna array signals by acoustic-optical devices (AOU) was treated in [2, 3]. The possibility of processing wideband signals received by a two-dimensional phased antenna array, with an optical system having an acoustic-optical input is indicated in [4].

Spatial-time processing of a wideband signal, $s(t) = \mathrm{Re}\{\dot{U}(t)\exp(j2\pi f_c t)\}$, received by a two-dimensional phased antenna array (Figure 1) is treated in this paper, and the possibility of eliminating the ambiguity of the readout of the angular coordinates of the signal source, which arises during the measurement process, is analyzed.

A structural schematic of an acoustic-optical unit for processing the signals of a two-dimensional phased antenna array, which contains M x N receiving elements, is shown in Figure 2, where 1 is a multichannel ultrasonic light modulator operating in the Bragg diffraction mode; 2 is an integrating lens with a focal distance of $f_{л}$. By performing a theoretical calculation of the distribution of the intesity of the stopped light beam at the output of the acoustic-optical unit (the output focal plane of lens 2) on analogy with [2, 3], it is not difficult to shown that it is described by the expression:

$$I_{out}(f_x,f_y) = \begin{array}{l} I_{\text{вых}}(f_x, f_y) = I_m \operatorname{sinc}^2\left[\frac{\pi\lambda H}{2}(f_x^2 - f_{x0}^2)\right] \operatorname{sinc}^2[\pi W f_y] |\dot{F}_U(f_x)|^2 \times \\ \times \frac{\sin^2 \pi M [L f_y - (f_x - f_{x0}) V\tau_y]}{\sin^2 \pi [L f_y - (f_x - f_{x0}) V\tau_y]} \frac{\sin^2 \pi N [l f_y - (f_x - f_{x0}) V\tau_x]}{\sin^2 \pi [l f_y - (f_x - f_{x0}) V\tau_x]}. \end{array} \qquad (1)$$

In (1), $I_m = (E_0 \alpha W D / 2\lambda f_л)^2$ is the maximum value of the intensity of the stopped field; E_0 and λ are the intensity and the wavelength of the incident light beam; α is the phase modulation index of the light field, which is proportional to the amplitude of the input signal; l is the spacing between the centers of the channels; D, W and H are the dimensions of one ultrasonic channel of the modulator along the OX, OY and OZ axes respectively (Figure 2); $L = Nl$, $f_{x\text{б}} = [f_{xb}] = (\sin\theta_b)/\lambda$; θ_b is the incident angle of the light on the ultrasonic light modulator (the Bragg angle); $f_{xc} = f_c/V$ is the spatial frequency corresponding to the carrier frequency f_c of the received signal; V is the propagation velocity of the oscillations in the ultrasonic light modulator; $f_x = \xi/\lambda f_л$, $f_y = \eta/\lambda f_л$ are the spatial frequencies; ξ and η are the coordinates in the output focal plane of the lens 2; $\tau_y = (d_y/v)\sin\beta$ and $\tau_x = (d_x/v)\sin\theta\cos\beta$ are the difference in the signal arrival times at adjacent elements of the phased antenna array, which are positioned at a distance d_y along each of the M horizontal rows (the OY axis) and at a distance d_x along the each of the N columns (the OX axis) respectively; β and θ are the elevation angle and azimuth of the signal source A (Figure 1); v is the signal propagation velocity in the medium; $\mathrm{sinc}\, z = (\sin z)/z$;

$$\dot{F}_U(f_x) = \int_{-\infty}^{\infty} \dot{S}_U(f)\,\mathrm{sinc}\,[\pi D(f_x - f_{x\text{б}} + f_{xc} + f/V)]\,df$$

characterizes the distribution of the intensity of the stopped light beam along the frequency axis f_x in accordance with the spectral density of the complex envelope of the received signal $\dot{S}_U(f)$.

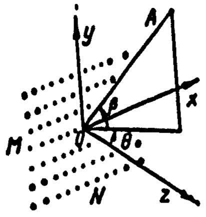


Figure 1.

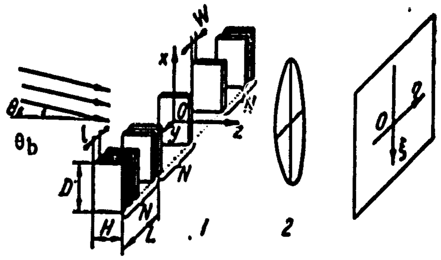


Figure 2.

As follows from (1), the distribution of the light intensity in the output plane of the lens consists of the periodically alternating sets of diffraction maxima. The sets, which are arranged with a period of $1/l$ along the f_y axis, characterize the "coarse" structure of the output optical channel. The coordinates of their centers satisfy the conditions:

$$f_y^{\text{coarse}} = f_y = (f_{xm} - f_{x\text{б}})\tau_x V/l + q/l, \quad (q = 0, \pm 1, \pm 2, \ldots), \tag{2}$$

where f_{xm} is the position of the diffraction maxima on the spatial frequency axis f_x.

The coordinates of the centers of the individual maxima, which characterize the "fine" structure of the output optical signal, satisfy

$$f_y^{fine} = f_y^p = (f_{xm} - f_{x0})\tau_y V/L + p/L, \quad (p = 0, \pm 1, \pm 2, \ldots). \tag{3}$$

It follows from (3) and (1) that the diffraction maxima of the "fine" structure have a repetition period of 1/L along the f_y axis and $1/(NV\tau_x - V\tau_y)$ along the f_x axis and make an angle with the f_x axis of $\phi_t = \arctan(\tau_y V/L)$.

If the spatial frequency bandwidth of the optical signal in the output plane of the acoustic-optical device is $\Delta f_{xc} = \Delta f_c/V$ and exceeds the period of the "fine" structure along the f_x axis, i.e.:

$$\Delta f_c > 1/(N\tau_x - \tau_y). \tag{4}$$

There arises the possibility of measuring the angle made by the "coarse" structure of the optical signal (by the set of diffraction maxima) with the axis f_x: $\phi_{coarse} = \arctan(\tau_x V/l)$.

For a radiation source with a zero elevation angle ($\theta = 0$), (4) assumes the form:

$$\Delta f_c > 1/N\tau_x. \tag{5}$$

Condition (5) requires that the correlation time of the received signal $1/\Delta f_c$ does not exceed the difference in the times for its propagation from the radiation source to the edge receiving elements of each row of the phased antenna array, something which is observed for wideband signals in a space-time sense.

When the angular coordinates β and θ of the signal source change with respect to the axial bearing direction ($\beta = \theta = 0$), the diffraction maxima of the "fine" and "coarse" structures are shifted along the f_y axis by the amounts of $\Delta f_y^{fine} = (f_{xm} - f_{xb})\tau_y V/L$ and $\Delta f_y^{coarse} = (f_{xm} - f_{xb})\tau_x V/l$ respectively with respect to their values when $\beta = \theta = 0$, in which case, $\Delta f_{y\,max}^{fine} = \pm(f_{xm} - f_{xb})\cdot|\tau_{y\,max}|V/L$ and $\Delta f_{y\,max}^{coarse} = \pm(f_{xm} - f_{xb})\,|\tau_{x\,max}|V/l$, where $\tau_{y\,max} = \max\{\tau_y\}$ and $\tau_{x\,max} = \max\{\tau_x\}$. For a unique measurement of the angular coordinates of the radiation source, it is essential that the maximum shifts of the diffraction maxima of the "fine" and "coarse" structures satisfy the conditions:

$$2|\Delta f_{y\,max}^{fine}| \leq 1/L, \quad 2|\Delta f_{y\,max}^{coarse}| \leq 1/l \tag{6}$$

which are equivalent to $d_y \leq \lambda_c$ and $d_x \leq \lambda_c$, which are the usual requirements of uniqueness for a phased antenna array. Here, λ_c is the wavelength corresponding to the center frequency of the signal spectrum f_c. It follows from (2), (3) and (6) that a unique determination of the angular coordinates of the radiation source, β and θ, is possible from the expressions:

$$\sin\beta = \frac{Lf_y^{\text{т}} - E[Lf_y^{\text{т}}]}{(f_{xm} - f_{x6})Vd_y/v}; \quad \sin\theta\cos\beta = \frac{lf_y^{\text{г}} - E[lf_y^{\text{г}}]}{(f_{xm} - f_{x6})Vd_x/v}, \qquad (7)$$

where E[z] is the integral part of z.

Expressions (7) also remain justified when a narrow band signal is received. However, $\dot{F}_U(f_x)$ in (1) for this case assumes the form $\dot{F}_U(f_x) = S_0 \operatorname{sinc}[\pi D(f_x - f_{xb} + f_{xc})]$, where S_0 is the maximum of the spectral density of the complex envelope of the signal.

When expressions (6) are violated, but condition (4) is satisfied, the angles β and θ are uniquely defined by the expressions:

$$\sin\beta = (\operatorname{tg}\varphi_{\text{т}})\,vL/Vd_y, \quad \sin\theta\cos\beta = (\operatorname{tg}\varphi_{\text{г}})\,vl/Vd_x \qquad (8)$$

[$\phi_T = \phi$, fine; $\phi_\Gamma = \phi$, coarse] by virtue of measuring the angles made by the diffraction maxima of the "coarse" and "fine" structures of the output optical signal with the spatial frequency axis $f_x(\phi_\Gamma, \phi_T)$.

In the special case of the reception of wideband signals by a linear phased antenna array (M = 1), layed out along the OX axis, the distribution of the light intensity (1) in the output plane of the acoustic-optical device assumes the form:

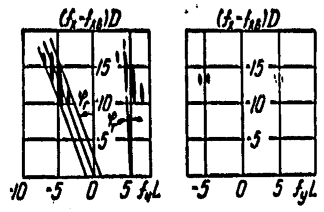
$$I_{out}(f_x, f_y) = I_{\max}(f_x, f_y) = I_m \operatorname{sinc}^2\left[\frac{\pi\lambda H}{2}(f_x^2 - f_{x6}^2)\right] \operatorname{sinc}^2[\pi W f_y] \times |\dot{F}_V(f_x)|^2 \frac{\sin^2 \pi N [lf_y - (f_x - f_{x6})V\tau_x]}{\sin^2 \pi [lf_y - (f_x - f_{x6})V\tau_x]}.$$

In this case, the output optical signal of the acoustic-optical device does not have a "fine" structure, and the determination of the true azimuth of the radiation source is possible only under the condition β = 0.

To illustrate the results obtained, the reception of a radio signal is considered, the center frequency of which is f_c, while the envelope has a rectangular spectrum:

$$S_U(f) = \begin{cases} S_0, & f \in [-\Delta f_c/2, \Delta f_c/2], \\ 0, & f \,\bar{\in}\, [-\Delta f_c/2, \Delta f_c/2]. \end{cases}$$

A calculation was carried out for the distribution of the intensity of the stopped light field at the output of the acoustic-optical device for the case of the following initial data: the receiving phased antenna array contains five rows (M) and 10 columns (N), and the spacing between the phased antenna array elements is $d_x = d_y = \lambda_c$; the difference in the arrival times of the signal at adjacent receiving elements along both axes is $\tau_x = \tau_y = 1/2\, f_c$ (β = 30°, θ = 35.3°); the spatial frequency in the output plane of the acoustic-optical unit, normalized for the resolving power of the ultrasonic light modulator, corresponding to the center frequency of the received signal, is $Df_{xc} = 13.75$.



(a) а (b) б

Figure 3.

The regions where the intensity of the stopped light field exceeds the level of $0.5I_m$ in the output plane of the acoustic-optical unit is shown in Figure 3 in normalized coordinates of $(f_x - f_{xb})D$ and f_yL for values of the parameter $\gamma = (\Delta f_c/V)/(1/D) = D\Delta f_{xc}$, which are the ratios of the spatial frequency bandwidth of the optical signal to the resolving power of the ultrasonic light modulator along the f_x axis with values of 7 and 1. It can be seen from Figure 3 that the dimensions of the region occupied by the diffraction maxima along the spatial frequency axis f_x increase proportionally to the spectral width of the signal being analyzed, Δf_c. When $\gamma = 7$ (Figure 3a), the extent of the optical signal along the f_x axis exceeds the period of the "fine" structure along this axis, $D/V(N\tau_x - \tau_y)$, by approximately two times, something which permits the realization of the capability of the measurement of the angles ϕ_{fine} and ϕ_{coarse}, and the determination of the elevation β and azimuth θ of the radiation source by employing equations (7) and (8). For $\gamma = 1$, as follows from Figure 3b, Δf_{xc} is approximately three times less than the period of the "fine" structure of the optical signal along the f_x axis, and it is practically impossible to read out the angles ϕ_{fine} and ϕ_{coarse}. In this case, the angular coordinates of the radiation source are determined on the basis of (7).

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ELECTRONICS AND ELECTRICAL ENGINEERING

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A DIGITALLY CONTROLLED ADAPTIVE PROCESSOR FOR AN ANTENNA ARRAY

Kiev IVUZ RADIOELEKTRONIKA in Russian Vol 22 No 2, Feb 79 pp 79-81

[Article by V.G. Sergeyev, I.N. Nikitina and Yu.S. Zakharov, manuscript received 26 Sep 78]

[Text] A device for processing the signals picked off of the elements of an array is shown in Figure 1. The signal at its output $U_3(t)$ represents the weighted sum of the input signals $U_i(t)$ with weighting factors of W_i:

$$U_3(t) = \sum_{i=1}^{n} U_i(t) W_i,$$

where n is the number of channels in the adaptive device; W_i is the transmission factor of the controlled attenuators.

Such a system can perform both spatial and time filtration. Several algorithms for finding the optimum set of weighting factors are well known, which have been proposed in [1 - 3].

The properties of an adaptive filter with a digital control loop are studied below. It is assumed that the adaptive filter contains n inputs. A processor which employs a modified gradient slope procedure [1] is used for processing the input signals.

It was shown in [1] that the weighting vector derived by means of this algorithm converges to an optimal vector corresponding the criterion of a minimum of the mean square error. The configuration of a processor which realizes this algorithm, with a digital design variant of the adaptive device with one uncontrolled channel is shown in Figure 1. The application of the adaptive filter being investigated here to the suppression of interference acting at its input is analyzed. The voltages at the adjacent inputs are distinguished by a time delay in the amount of $\Delta\tau$. Normal white noise is employed as the interference model, where this noise is colored by the filter having a Q of 20.

Two variants of the control circuit design are studied: in the first, the multiplication operations are performed by analog devices while the sampling of the control signal at the output of the multiplier are quantized in amplitude; in the second, the sampling and quantization of the signal are accomplished at the inputs of the digital multipliers. In both cases, the real weighting factors can vary discretely with a step of Δb. The complex weighting factors in the model are realized by means of replacing each complex controlled channel with two real ones: a direct and a quadrature one.

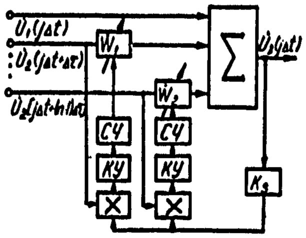

Figure 1.

[СЧ and НУ not expanded in text]

The voltage at the output of the adaptive filter (Figure 1) is:

$$\dot U_3(j\Delta t) = \dot U_1(j\Delta t) + \dot U_2(j\Delta t + \Delta\tau)\dot W_1 + \dot U_2(j\Delta t + 2\Delta\tau)\dot W_2 +$$

$$+ \dots + \dot U_2[j\Delta t + (n-1)\Delta\tau]\dot W_{n-1};$$

$$\dot W_n = \frac{k_s}{1 - k_s\hat\sigma_2^2}(\hat R_{12}(n\Delta\tau) + \hat R_{22}(\Delta\tau)[\dot W_{n-1} + \dot W_{n+1}] + \hat R_{22}(2\Delta\tau)[\dot W_{n-2} + \dot W_{n+2}] + \dots).$$

The Λ symbol indicates estimation of the parameters; σ_2^2 is the noise power in the controlled channels. The cross-correlation function $R_{12}(n\Delta\tau)$ of the signals $U_1(j\Delta\tau)$ and $U_2(j\Delta\tau + n\Delta\tau)$ which are quantized in amplitude and digitized in time is computed by the usual method [3]. $R_{22}(n\Delta\tau)$ is the cross-correlation function of the voltages shifted by the time nΔτ.

The dispersion of the signal at the output of the dual-channel adaptive filter is:

$$\sigma_3^2 = \sigma_1^2 + \sigma_2^2\hat m_s^2 + 2\hat m_s\rho_{12}(\Delta\tau)\sigma_1\sigma_2,$$

and at the output of a three-channel filter is:

$$\sigma_3^2 = \sigma_1^2 + \sigma_2^2(\hat m_{s1}^2 + \hat m_{s2}^2) + 2\hat m_{s1}\rho_{12}(\Delta\tau)\sigma_1\sigma_2 +$$

$$+ 2\hat m_{s2}\rho_{12}(2\Delta\tau)\sigma_1\sigma_2 + 2\hat m_{s1}\hat m_{s2}\rho_{12}(\Delta\tau)\sigma_1\sigma_2,$$

where
$$\hat m_s = \frac{k_s\hat R_{12}(\Delta\tau)}{1 - k_s\hat\sigma_2^2};$$

$$\hat{m}_{s1} = \frac{k_s[\hat{R}_{12}(\Delta\tau) + \hat{R}_{22}(\Delta\tau) W_2]}{1 - k_s\hat{\sigma}_2^2};$$

$$\hat{m}_{s2} = \frac{k_s[\hat{R}_{12}(2\Delta\tau) + \hat{R}_{22}(\Delta\tau) W_1]}{1 - k_s\hat{\sigma}_2^2}.$$

We define the noise suppression factor at the output of the adaptive processor as $K_n = \sigma_3^2/\sigma_1^2$. We assume that the noise power at the inputs to the channels is equal to unity ($\sigma_1^2 = \sigma_2^2 = 1$). Then the maximum noise suppression factors for the two and three-channel automatic compensators will be correspondingly equal to:

$$K_n = (1 + \hat{m}_s)^2, \quad K_n = (1 + \hat{m}_{s1} + \hat{m}_{s2})^2.$$

The suppression factor $K_n(q)$ was computed theoretically as a function of the control signal quantization step for the condition of normalization of the process at the output of the multiplier. The results of the calculations are shown in Figure 2 by the solid line, where the symbol K_n in the maximum noise suppression factor for the analog control loop.

In case the process at the outputs of the multipliers is not normalized, then by approximating the laws governing the output signals of the multipliers with a χ^2 distribution, it can be shown that the decrease in the maximum noise suppression factor will amount to 1.5% - 2.0% for q = 1.0.

The discrete change in the weighting factors with a step of Δb should be treated as the introduction of quantization noise into the channels, where this noise is statistically independent of the input and output signals.

The theoretical value of the noise suppression factor is shown in Figure 3 as a function of the size of the weighting factor step Δb and as a function of the number of adaptive processor channels.

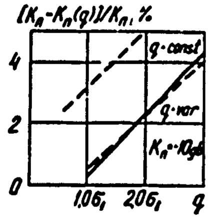

Figure 2.

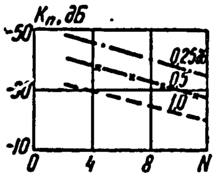

Figure 3.

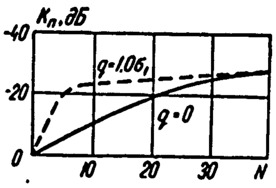

Figure 4.

The influence of the quantization of the control signal samples when $\Delta b = 0.25$ dB can be neglected, since in this case, the maximum noise suppression factor will be determined primarily by the quantization step of the weighting factors and the number of adaptive processor channels.

Modeling of a dual-channel adaptive processor with digital control was carried out on an YeS-1030 digital computer. Figure 4 illustrates the process of determining the noise suppression factor.

Since in the adaptation process the voltages at the outputs of the multipliers fall off, then as soon as the fourth or fifth adaptation cycle is reached, the quantizing multilevel devices become dual-level ones. To maintain a constant number of quantization levels in the adaptation process, one can vary the quantization step. The results of modeling for this case (q is variable) are shown in Figure 2. A processor, the control circuit of which was designed in a configuration having quantizers at the inputs of the digital multipliers, was also simulated.

The modeling results confirmed the theoretical calculations and showed that when the number of quantization levels is more than four to six, practically no reduction is observed in the noise interference suppression factor for the given processor circuit, as compared to a processor with analog control

We will note in conclusion that the noise suppression factor of an adaptive processor for the case of control signal quantization with a step equal to the mean square value of the signal at the output of the multiplier is degraded by 0.4% - 0.5% overall. The use of six-level quantizers at the inputs of the digital multipliers makes it possible to practically avoid the reduction in the noise suppression factor related to the encoding of the control signal.

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OPTIMAL SPATIAL PROCESSING OF A SIGNAL AGAINST A BACKGROUND OF INTERFERENCE FROM A SUBJACENT SURFACE

Kiev IVUZ RADIOELEKTRONIKA in Russian Vol 22 No 2, Feb 79 pp 54-59

[Article by V.I. Samoylenko and O.D. Uglov, manuscript received 26 Nov 78]

[Text] The question of optimal spacing processing (filtration) of a signal in an antenna system against a background of clutter from a subjacent surface is treated from the viewpoint of optimal detection theory. A spatial correlation function is given for the interference from the subjacent surface. It is demonstrated that the optimization of the antenna can be accomplished separately in the azimuthal and elevation planes. The gain in the signal/interference ratio is defined, and the influence on it of the a priori ambiguity of the target coordinates is taken into account.

An improvement in the detection characteristics of radar systems in the presence of clutter from a subjacent surface can be achieved when all of the a priori information on the spatial characteristics of the signal and interference is taken into account in solving the detection problem.

The problem of detecting a space-time signal against a background of gaussian interference, formulated in terms of a test of static [sic] hypotheses has been solved in general form (for example, [1]). The optimal spatial processing operations are determined from the probability ratio for the spatial field of the signal and interference at a fixed point in time [2]. A phased antenna array (FAR) makes a discrete sample of finite size from the field realization in a limited region of space.

Writing the probability ratio in explicit form requires knowledge of the spatial correlation matrix of the interference, which can be derived from the spatial correlation function describing the inter-relationship of the interference at two points in space.

To determine the spatial correlation function of the interference, we shall use a phenomenological model of the subjacent surface: the radio signal is reflected from a large number of reflectors with random, equally probable coordinates within a resolution element, the reflectivity of each of which is approximately the same. Such a model yields a normal distribution of the quadrature components of the interference [3].

We define the spatial correlation function of the interference in the form [4]:

$$R_{v_1v_2}=\overline{V_1V_2^*} \qquad (1)$$

where V_1 and V_2 are the interference voltage at the output of the first and second receiving elements of the FAR respectively, which are positioned at the points in space under consideration; the line means averaging over the set, while an asterisk means a complex conjugate quantity.

The cross-correlation coefficient is

$$\rho_{v_1v_2}=\frac{R_{v_1v_2}}{\sqrt{R_{v_1v_1}R_{v_2v_2}}}. \qquad (2)$$

Such a definition of the spatial correlation function of the interference from the subjacent surface was derived from a more general space-time correlation function, if it is assumed that the sounding signal is narrow band, i.e., the delay of the modulation envelope (amplitude-phase) of the signal over the region of space in which the sample is taken can be neglected.

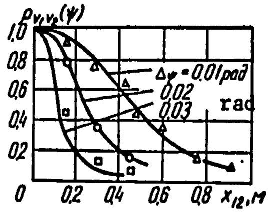


Figure 1.

The following assumptions were made in deriving the expression for the spatial correlation function: the earth's surface is considered to be flat; the reflectors are located in the far field; we neglect multiple returns; the radiation directional pattern is approximated by a gaussian curve; the transmitting and receiving antennas are positioned at a low height, i.e., the return is considered for the case of a small elevation angle.

When the limitations indicated above are taken into account, the spatial correlation function is:

$$R_{v_1v_2}=R(0)\,\rho_{v_1v_2}(\psi)\,\rho_{v_1v_2}(\varphi), \qquad (3)$$

where ψ and ϕ are the azimuth and elevation respectively.

In expression (3), the correlation function for the azimuth is

$$\rho_{v_1v_2}(\psi)=\exp\left\{-\frac{\Delta_\psi^2}{1,36}\left[\frac{2\eta}{\lambda}x_{12}\cos\psi_{01}\right]^2\right\}\times$$
$$\times\left\{-j\frac{2\eta}{\lambda}[x_{12}\sin\psi_{01}+y_{12}\cos\psi_{01}]\right\} \tag{4}$$

and for elevation:

$$\rho_{v_1v_2}(\varphi)=\cos\left(\frac{2\pi}{\lambda}z_{12}\Delta_\varphi\right)\exp\left\{-j\frac{2\pi}{\lambda}z_{12}\sin\varphi_{01}\right\}. \tag{5}$$

Here x_{12}, y_{12} and z_{12} are the distances between the receiving antennas in terms of unit vectors of a cartesian system of coordinates; ψ_{01} and ϕ_{01} are the azimuth and elevation of the center of the irradiated section of the subjacent surface; λ is the wavelength; Δ_ψ is the width of the radiation directional pattern in an azimuthal plane; Δ_ϕ is the width of the radiation directional pattern in the elevation plane.

The coefficient R(0) is the dispersion of the interference from the subjacent surface, defined on the basis of the basic radar formula:

$$R(0)=G_{v_1v_2}^2=\frac{G_{\text{прд}}\sqrt{G_1G_2}\,\lambda^2P_{\text{прд}}\sigma_{\text{пп}}(\varphi_{01})\,\Delta_\varphi}{(4\pi)^3R^3}, \tag{6}$$

where $G_{\text{прд}}$ is the gain of the transmitting antenna; $P_{\text{прд}}$ is the power radiated by the transmitter; R is the range to the irradiated section of the subjacent surface; Δ is the range resolution element (it can be determined either by the width of the radiated pulse or by the width of the directional pattern in the elevation plane); $\sigma_{\text{пп}}$ (ϕ_{01}) is the specific effective dispersion surface area of the subjacent surface; G_1 and G_2 are the gains of the receiving antennas.

The spatial correlation function of the interference in the azimuthal plane is shown in Figure 1 for the case of $\psi_{01} = 0$ and $\lambda = 0.03$ m. Statistical modeling which was performed on a computer, the results of which are shown in the same figure, showed good agreement with the curves derived from expression (4).

An optimum receiver generates either a probability ratio or a unique function of it (for example, the logarithm). In the case of normal interference, the logarithm of the probability ratio can be derived in the form [4]:

$$l(\|Y\|)=-\|Y\|^{T}\|R^{-1}\|\|S\|+\frac{1}{2}\|S\|^{T}\|R^{-1}\|\|S\|, \tag{7}$$

i.e., the optimal processing is linear and reduces to correlation processing. In expression (7), all the quantities on the right side are complex and the following symbols are used: $||Y||$ is the input signal vector, $||Y|| = ||S|| + ||n||$; $||n||$ is the interference vector, which includes the interference from the subjacent surface and the internal receiver noise, $\|n\| = \|n_{ss}\| + \|n_n\|$; $\|R^{-1}\|$ is the inverse correlation matrix of the spatial interference; $\|S\|$ is the vector of the anticipated signal, an element of which is $S_i = S_0 \exp\{i\langle k\vec{r}_i\vec{u}_0\rangle\}$; $\vec{r}_i$ is the radius vector of the i-th receiver; $\vec{u}_2$ is the unit vector of the direction of signal arrival.

The first term in expression (7) is the minimally adequate statistic [4], which defines the form of the processing:

$$q = \|Y\|^{\tau}\|R^{-1}\|\|S\|, \tag{8}$$

while the second term is the signal/interference ratio at the output of the optimal processing system:

$$\mu = \|S\|^{\tau}\|R^{-1}\|\|S\|. \tag{9}$$

An optimal processing system performs the multiplication of the input signal vector by the vector of the optimal processing weighting factors, where this vector is defined in accordance with (8) in the form:

$$\|G\| = \|R^{-1}\|\|S\|. \tag{10}$$

The $\vec{r}_i$ radius vector for the position of the i-th element of the receiving system can be represented by a set of three numbers (x_i', x_i'', x_i''') in any system of orthogonal spatial coordinates (X', X'', X'''). The spatial correlation function of the interference from the subjacent surface can be factored in cartesian coordinates, something which follows from expression (3), (4) and (5), i.e., represented by a product of the form

$$R(\vec{r}_m - \vec{r}_n) = R_x(x_{mn})R_y(y_{mn})R_z(z_{mn}). \tag{11}$$

In this case, the matrices included in expressions (7)-(10) can be treated as block matrices (in cartesian coordinates, and by employing the direct product (the kronecker product), one can write

$$\|R\| = \|R_x\| \otimes \|R_y\| \otimes \|R_z\|, \tag{12}$$

$$\|S\| = \|S_x\| \otimes \|S_y\| \otimes \|S_z\|, \tag{13}$$

where $\otimes$ is the symbol for the direct product of the matrices. Taking the properties of direct products into account [5], we rewrite expression (8):

$$q = \|\mathring{Y}\|^{\tau}[\|R_y\| \otimes \|R_y\| \otimes \|R_z\|]\|S_x\| \otimes \|S_y\| \otimes \|S_z\| =$$
$$= \{[\|\mathring{Y}\|^{\tau}\|R_x^{-1}\|\|S_x\|]^{\tau}\|R_y^{-1}\|\|S_y\|\}^{\tau}\|R_z^{-1}\|\|S_z\|. \tag{14}$$

Here $||\overset{\circ}{Y}||$ is the $||Y||$ matrix, the spatial variable in which is written in cartesian coordinates.

It follows from expression (14) that optimal spatial processing of a signal against a background of interference from a subjacent surface can be carried out separately for each independent spatial coordinate. This conclusion is justified for any type of antenna, including the case where those assumptions are made with which expressions (3) - (5) were derived and the sounding signal can be considered a narrow band one. This permits a substantial simplification of the realization of the optimal processing system and a reduction in the volume of computations when processing in digital form, which is possible when using a phased antenna array.

The result of optimal spatial processing when expression (14) is used can be represented inthe form

$$q = q_x q_y q_z. \tag{15}$$

Consequently, the synthesis and analysis of the spatial processing system can be carried out separately for each spatial coordinate, taking (14) and (15) into account. Algorithm (14) is the widely known row -column processing algorithm, used in phased antenna arrays. Thus, in interference from a subjacent surface, the application of line-column processingdoes not lead to the degredation of the processing result.

We shall consider the realization of optimal spatial processing using a phased antenna array with a plane aperture. In this case, the vectors of theweighting factors for optimal processing with respect to the orthogonal coordinates can be defined as:

$$\begin{aligned} \|G_x\| &= \|R_x^{-1}\| \, \|S_x\|; \\ \|G_y\| &= \|R_y^{-1}\| \, \|S_y\|. \end{aligned} \tag{16}$$

The elements of these vectors are determined from expressions of the form:

$$G_m = \sum_{n=1}^{N} R_{mn}^{-1} S_n,$$

where N is the number of elements in a row (or column) of the phased antenna array.

The vector of the weighting factors for optimal spatial processing is the optimal amplitude-phase distribution in the phased antenna array aperture, which defines the optimum directional pattern (DN) of the optimum antenna. The optimality of the amplitude-phase distribution in the aperture of the phased antenna array and its directional pattern, i.e., of the spatial processing of the signal, performed by such an antenna against a background of interference, follows from the fact that they are derived from the minimally sufficient statistic (8), i.e., on the basis of the criterion of a maximum of the probability ratio of [4].

It is necessary to take into account the fact that the optimal weighting processing coefficients are complex quantities, and for this reason, they can be realized in the form of a series connected phase shifter and attenuator. Thus, the realization of the optimal spatial processing by means of a phased antenna array is possible and requires the addition of an attenuator to the phased antenna array structure, something which presents no technical difficulties.

The analysis of optimal processing systems which operate in normal interference can be based on the magnitude of the signal/interference ratio [4], defined by expression (9). We shall determine the gain derived by virtue of optimal processing as compared to equally weighted summing, as:

$$\eta_b = \frac{\mu_{ort}}{\mu_{b\ kor}}$$

where μ_{ort} is the signal/interference ratio at the output of the optimal spatial processing system; $\mu_{b\ kor}$ is the signal/interference ratio at the output of a system of the same geometry for the case of equally weighted summing of the signals of the phased antenna array elements (optimal in white noise) for the case where correlated spatial interference acts on the array.

The calculation of ν_b under the condition that the signal either arrives normal to the aperture or a system generating a plane phase front in the direction of the signal exists, yields the expression

$$\eta_b = \eta_б = \frac{1}{M^2} \sum_{m,}^{M} \sum_{n=1}^{M} R_{mn}^{-1} \sum_{m,}^{M} \sum_{n=1}^{M} R_{mn}, \qquad (17)$$

where M is the number of receiving elements in the optimal spatial processing system; R_{mn} and R_{mn}^{-1} are the elements of the direct and inverse correlation matrices of the interference respectively.

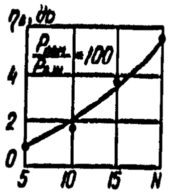


Figure 2.

Key: A. η_b, dB;
B. $\frac{P_{\text{interference}}}{P_{\text{white noise}}} = 100.$

Expression (9) was derived with the assumption that the direction of signal arrival $\vec{u}_0$ is known a priori, something which is not observed in practice. Usually, the probability characteristics of the direction of signal arrival are known. Thus, one can assume in the detection problem that the probability distribution of the angular coordinate of the target is uniform. In this case, the processing result, determined by the magnitude of the signal/interference ratio, will be worse because of the error in the anticipated direction of signal arrival. By transforming expression (9), one can take into account in it the random error in the anticipated direction of signal arrival in the processing system, i.e., the a priori ambiguity of the angular coordinates of the target when detecting it. By averaging with respect to the random error in the anticipated direction of signal arrival, we obtain the mean signal/interference ratio for the case of a priori ambiguity of target coordinates in the form:

$$\tilde{\mu} = \mu - \Delta\mu, \tag{18}$$

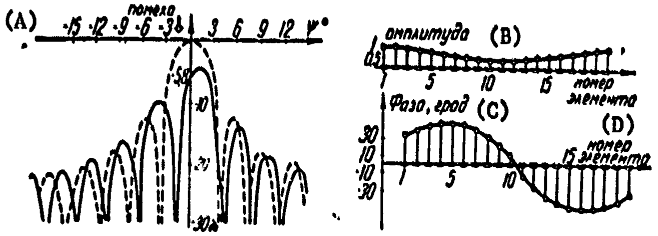
where

$$\Delta\mu = \frac{(\sigma_\theta kd\cos\Theta)^2}{2}\sum_{m,}^{M}\sum_{n=1}^{M} R^{-1}_{mn} n^2 \exp(jkd(m-n)\sin\Theta_0), \tag{19}$$

where σ^2_θ is the dispersion of the angular deviation of the signal arrival from the a priori value in terms of the angular coordinate Θ (either elevation or azimuth); d is the spacing between the elements of the phased antenna array.

It follows from expression (18) that the a priori ambiguity of the target coordinates leads to a certain reduction in the average signal/interference ratio at the output of the spatial processing system, the size of which is determined by formula (19). Knowing the width of the radiation directional pattern, i.e., the range of ambiguity of the target coordinates, and by specifying the permissible size of $\Delta\mu$, the problem of determining the requisite number of beams in the detection system and the number of phased antenna array elements can be solved by employing expressions (18) and (19).

Computer modeling was carried out to obtain numerical results. The vector of the optimal weighting coefficients was computed from expressions (16). The correlation matrix of the interference was reduced by an iteration procedure. The improvement in η_b due to optimal spatial processing in the azimuthal plane is shown in Figure 2 as a function of the number of elements of the receiving phased antenna array. It was assumed that the dimensions of the aperture of the transmitting and receiving antennas are the same. The optimal directional pattern of the phased antenna array is shown in Figure 3a in the elevation plane (solid line), calculated on a computer for the case of a high range resolving power, where the angular width of the interference amounts to 15% of the width of the directional pattern. The initial directional pattern, corresponding to uniform summing is shown with the dashed line. In this case, the improvement from optimal processing is $\nu_b \approx 19$ dB for $N = 20$ and $P_{inter}/P_{white\ noise} = 100$. The optimal amplitude and phase distributions are shown in Figure 3b for this interference situation. It can be seen from Figure 3 that the directional pattern has a deep trough in the direction of the interference. This assures a high signal//interference ratio at the antenna output.



а
(a)

б
(b)

Figure 3.

Key: A. Interference;
B. Amplitude;
C. Phase, degrees;
D. Element number.

Optimal spatial processing of a radar signal against a background of interference from a subjacent surface, as the results of calculations demonstrate, can yield a substantial gain in the signal/interference ratio at the output of a phased antenna array, i.e., it can assure high detection characteristics, not precluding the use of traditional time processing methods in this case, for example, MTI systems.

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ENGINEERING AND EQUIPMENT

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ON A DOSIMETRY METHOD FOR LASER RADIATION

Leningrad OPTIKO-MEKHANICHESKAYA PROMYSHLENNOST' in Russian No 2, 1979 pp 50-54

[Article by M. I. Gvozdev, A. I. Kirillov, V. I. Kishko, V. F. Morskov, A. S. Naumov and N. D. Ustinov, submitted to the editors 2 Feb 78]

[Text] Definition of the Problem

Laser radiation dosimetry consists primarily in measuring the intensity of illumination or the amount of energy illuminating different regions of the eye, the human organ most sensitive to radiation.

The degree to which the retina of the eye is affected depends on:
- --the size of the pupil, which varies relative to the brightness of the ambient background;
- --the size of the image spot on the retina, which is governed by the pupil's diameter (due to diffraction), by heterogeneities and aberrations of the eye's optic media, and also by the focal length of the eye and the geometric parameters of the beam of radiation;
- --the intensity of illumination in the image spot on the retina, which is governed by the energy of the radiation entering the eye (i.e., by the diameter of the pupil and the intensity of its illumination), and by the transmission factor of the ocular media and the size of the spot itself;
- --the reflecting and absorbing property of the retina;
- --the length of time the retina is irradiated, which can be governed by the time parameters of the laser radiation, the time of the blink reflex, or by the time required to observe objects under laser radiation.

All of the listed parameters have to be taken into account in the process of setting standards of radiation and finding methods and means for dosimetry in the 0.4-1.2-μm spectral region.

The safety standards at present set the level for radiation of the cornea on the basis of the criterion for affection of the retina. This is done to simplify practical application of the norms in the field of industrial hygiene and because, as is pointed out in [7], for example, the exact dimensions of the image and the radiation energy distribution on the retina can not be determined reliably.

However, the result is that, first of all, the permissible levels of exposure are given only for collimated beams of specified divergence and do not cover the whole gamut of radiations with indeterminate beam parameters. Secondly, in the process of setting the standards, the medical people come up with substantial safety factors due to the spread of the eyes' biological and optical characteristics in different individuals. Thirdly, this approach can not provide us with clear recommendations as to dosimetry methods and means suitable for beams of whatever divergence.

When setting standards for intensity of illumination of the retina, moreover, one can disregard the geometrical characteristics of laser radiation at the eye's entry, pupil size, transmission factor of the ocular media and the reflecting and absorbing property of the retina. It will suffice to specify the permissible density of energy absorbed by the retina for a range of radiation-spot sizes (for example, on the basis of thermal or other models).

In this case, questions relative to certain biological uncertainties due to the spread of eye characteristics have to be referred to appropriate areas of the dosimetry of laser radiation, not to the medical people and others who are working up the health norms. And dosimetry, to wit, must with due accuracy and reliability take into account all of the above-mentioned factors affecting the degree of retinal injury.

Set forth below are some data on selection of characteristics of the optical system for an instrument, and data on a method for measuring intensity of illumination on the retina of the eye.

Optical Characteristics of a Lens for Measuring Intensity of Illumination of the Retina

In view of the fact that it is dangerous and, as yet, technically impracticable to measure illumination intensity directly on the human retina, it is expedient to develop a model of the eye, i.e., a lens which produces images of objects analogous to the images of these objects on the retina, and to measure the light intensity of that image. Since the images produced by the human eye on the retina may be extremely small and therefore not convenient for study, it might be possible to create a lens in which the images are larger than those on the retina but remain similar to them; i.e., the relationships of the linear dimensions and also the distribution of energy in the lens image are subject to the same laws as in the image produced by the human eye. Hence, for any part of a radiating object the following relationship between the dimensions of the images produced by a human eye l'_{eye} [subscript гл=eye] and a dosimeter lens [subscript об=lens] l'_{lens} must hold:

$$l'_{\text{об}} = M l'_{\text{гл}}, \tag{1}$$

where M is a constant.

It is necessary to determine the optical characteristics required of the lens in order that condition (1) be satisfied.

Condition (1) means that the linear magnification of the lens β_{lens} must exceed the eye's magnification β_{eye} M times

$$\beta_{об} = M\beta_{гл}.$$

For objects, the distance to which is much greater than the optical system's focal length, linear magnification is directly proportional to focal length, hence

$$f'_{об} = Mf'_{гл}, \tag{2}$$

where f'_{lens} is the back focal length of the lens and f'_{eye} is the equivalent focal length of the eye.

In this manner the fulfillment of condition (1) in the case of long objects is assured by the fact that $f'_{lens} = Mf'_{eye}$.

However, for the images of objects which have small angular dimensions--in particular, for images of direct and mirror-reflected laser radiation--aberrations of the optical system and heterogeneities of the optic media are of great import. In reference [2] there is an experimental curve for the relationship between the limit of the eye's resolving power and the diameter of the pupil; and it is demonstrated that the resolving power, which is uniquely connected with the dimensions of the image of a parallel beam, is governed by diffraction, heterogeneities and aberrations of the human eye.

Consequently, in order that condition (1) be satisfied in the case of point objects it is necessary to simulate the diffraction, the heterogeneities and the aberrations of a human eye.

The diffraction af an optical system depends on the diameter of the entry pupil. Condition (1) will be satisfied if

$$\delta_{об} = M\delta_{гл},$$

where δ_{lens} is the radius of the diffraction scattering circle in the lens and δ_{eye} is the radius of the diffraction scattering circle in the eye. The radius of the diffraction scattering circle for an optical system is expressed by the formula

$$\delta = f'\frac{1.2\lambda}{D},$$

where f' is equivalent back focal length, λ is the radiation wavelength and D is the diameter of the entry pupil.

Thus, in order that $\delta_{lens} = M\delta_{eye}$, taking (2) into account, it is necessary that

$$D_{об} = D_{гл}. \tag{3}$$

This equation signifies also that equal radiation fluxes go into the eye and the lens. It is not difficult to show that satisfying the equation of the entry pupils of lens and eye ensures one more very important lens characteristic, which is that when lens and eye are focused at one and the same distance a_1 the diameters of the scattering circles in the lens and the eye from a point source situated at a distance a_2, different from a_1, are bound by the relationship

$$d_{\text{об}} = M d_{\text{гл}}, \qquad (4)$$

where d_{lens} is the diameter of the scattering circle produced by the lens and d_{eye} is the diameter of the scattering circle produced by the eye.

Hence, for any number of point radiating objects situated within the field of view of the lens (and eye), a correspondence (similarity) of the fine structure of the images produced by lens and eye will obtain.

Since the diameter of the pupil of the human eye varies from 2 mm to 8 mm depending on the illumination, one should be able to vary the diameter of the lens entry pupil within the same limits.

The heterogeneities of ocular material play a substantial role in forming the luminous spot on the retina, but it is inadvisable to simulate them in a lens since they are of irregular nature and they may vary considerably from person to person and from eye to eye in an individual.

If the light intensity of the image produced by this lens is of a safe level, one will be able to say with confidence that the level of light intensity on the retina is safe regardless of the degree of heterogeneity of eye's material since the heterogeneities always "smear out" an image.

The most dangerous, from the point of view of effect on the retina, are axial beams of radiation since the image of them is produced in the fovea centralis (the most vulnerable and the most valuable area), but the dimensions of the images are minimal. Consequently, it is necessary to take into consideration only the chromatic and spherical aberrations on the eye's visual axis.

In the case of monochromatic radiation the eye's refraction can be corrected optimally for a given wavelength, and there will be no chromatic blurring of the image. It would therefore seem inadvisable to simulate chromatic aberration; still, chromatic aberration will unavoidably show up during the operation of laser units simultaneously on several frequencies (e.g., on the basic frequency and harmonics and so on). It can be computed according to the formula

$$\Delta f'_{(D-\lambda_{\text{об}})} = \frac{M^2 f'_{\text{гл}} \Delta f_{(D-\lambda_{\text{гл}})}}{f'_{\text{гл}} + \Delta f_{(D-\lambda_{\text{гл}})}(1-M)}, \qquad (5)$$

where f'_{eye} is the equivalent focal length of the eye for a wavelength D; $\Delta f'_{(D-\lambda_{\text{гл}})}$, $\Delta f'_{(D-\lambda_{\text{об}})}$ are the longitudinal chromatic aberrations of the eye and of the lens for wavelength λ.

In this case, the chromatic aberrations of the eye for wavelengths F and C amount to 0.23 and 0.12 mm, respectively [3].

Spherical aberration is quite varied in different eyes and at different focusings. It is inadvisable to simulate it too, as with heterogeneities of ocular material. It is necessary to synthesize a lens such that the spherical aberration spot on the axis be smaller than the diffraction spot.

The Results

Figure 1 shows a diagram of the optical system of the device and Figure 2 its physical appearance.

The lens 1, 2 was computed using the above-mentioned specifications and is an uncemented two-lens optical system. Figures 3 and 4 present graphs of the chromatic and spherical aberrations of the lens.

The diameter of the lens-aperture diaphragm is variable from 2 to 8 mm.

Proceeding from requirements as to precision of the focusing mechanism and technological limitations in fabricating the field diaphragm assembly, the value chosen for M is $\sim \sqrt{10}$.

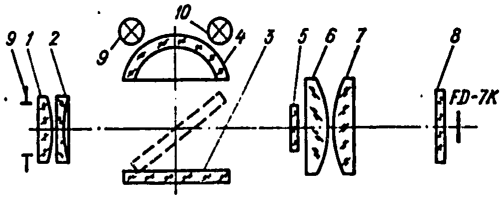

Figure 1. Optical System of the Device

The lens produces an image in the plane of the field diaphragm 5, the diameter of which can be varied in steps: 0.03, 0.06, 0.09, 0.15, 0.21, 0.6, 0.9 and 1.5 mm. This assembly of diaphragms makes it possible to evaluate size of image and enables ample selection of radiation sources and background sources. A condenser 6, 7 transmits the image of the entry pupil to the sensitive surface of an FD-7K photodetector. An assembly of three interchangeable light filters 8 permits a 1000-fold expansion of the dynamic range.

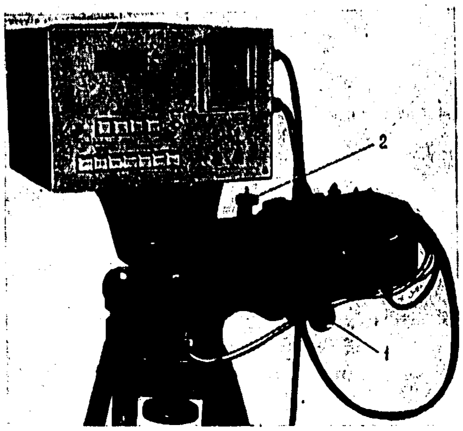

Figure 2. Physical appearance of the device.

The problem of aiming the device at the emitting object, which has a small visible angular dimension, was solved by including in the optical system an aiming channel consisting of lens 1, 2, movable mirror 3, phosphorescent coordinate screen 4, and type LUF-4 fluorescent lamps for screen illumination.

In the process of seeking and aiming at an emitting object, the mirror 3 directs the radiation at the screen 4; the angle of the field of view is governed by the size of the screen and is in this case 20°. The screen's sensitive element is made of a phosphor with a zinc sulphide base activated by copper and cobalt--ZnS-Cu-Co--and works on the principle of quenching, which makes possible prolonged observation of the effect of infrared rays. Threshold sensitivity of the screen in the 0.55-1.4-μm region is 10^{-5}W/cm^2 in continuous mode under optimum conditions of excitation $E_{uv}=$ $\approx 1\text{-}2 \cdot 10^{-4}$W/cm^2. In the region below 0.55 μm the screen functions like ground glass.

The operator, watching the light spot (or quenching) of the screen, notes the coordinates of the center of the spot and, by turning the azimuth and and elevation screws 1, 2 (Figure 2), lines up the center of the image spot with the center of the screen. When the radiation is being emitted in separate pulses this operation is performed in the course of 1-2 radiation pulses. Aiming accuracy is 7-10'.

In measuring mode the movable mirror is retracted and the radiation passes to the diaphragm 5 (Figure 1).

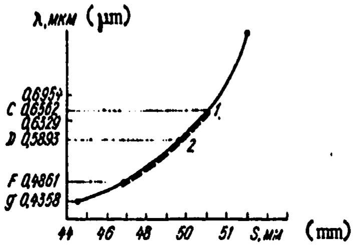

Figure 3. Chromatic aberration curve for lens (1) and eye (2).

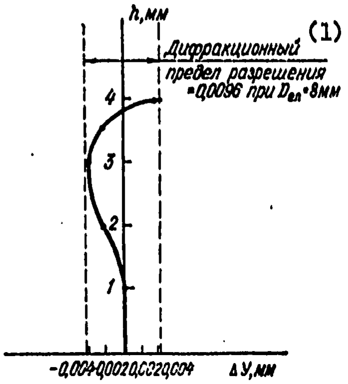

Figure 4. Transverse spherical aberration curve for lens (S=∞, λ=0.5893). 1-diffraction limit of resolution equals 0.0096 when D_{eye}=8 mm.

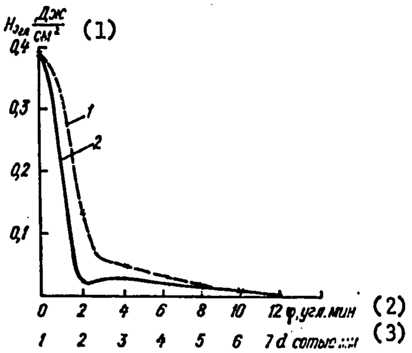

Figure 5. Energy level of retinal illumination $H_{E_{eye}}$ as a function of the angle φ between the visual axis and laser beam axis (curve 1) and as a function of diaphragm diameter d (curve 2). 1-$H_{E_{eye}}$ in J/cm^2; 2-φ in minutes of angle; 3-d in hundredths of a mm.

Figure 5 shows the distribution of illumination energy in the spot image of a modulated LG-126 laser beam (λ =0.63 um, τ_{imp}=120 μs) on the retina of a human eye with accommodation of the eye at infinity. Curve 1 was plotted with the field diaphragm aperture fixed at 30 μm diameter (angle size 2'); the device was rotated successively in one of the planes by an angle φ=2' and readings taken off the recorder. For the plotting of curve 2, the optical axis of the device was kept in alignment with the radiation beam axis; the drum with the field diaphragms was successively keyed and recorder readings taken.

The amount of illumination in the plane of the field diaphragm was determined in this case according to the formula

$$H_{\text{э}_{\text{пр}}} = \Delta P_i / \Delta S_i,$$

[subscript np = transmitted or transmission] where ΔP_i is the difference in recorder readings for two successive diaphragms, in J; ΔS_i is the difference between the areas of these diaphragms, in cm^2. The values for intensity of retinal illumination may be written thus:

$$H_{\text{э}_{\text{гл}}} = \left(\frac{f'_{\text{об}}}{f'_{\text{гл}}}\right)^2 \frac{\tau_{\text{гл}}}{\tau_{\text{пр}}} H_{\text{э}_{\text{пр}}}, \tag{6}$$

where τ_{eye}=0.46 is a factor accounting for transmission of the eye's transparent material and the absorption of energy by the retina at λ = =0.63 μm [4, 5]; τ_{trans}=0.68 is the transmission factor of the optical system; f'_{eye}=17.1 mm is the equivalent focal length of the human eye; f'_{lens}=54.1 mm is the focal length of the lens.

On the ordinate axis (Figure 5) are plotted the values, computed for the eye per formula (6), of $H_{E_{eye}}$--the retinal illumination energy for each successive angle φ and each diameter d of the retinal image upon keying of the diaphragms. The discrepancy between curves 1 and 2 is attributable to the asymmetry of the laser radiation spot.

Conclusions

1. The existing procedure of setting standards for the irradiation of the cornea of the eye but not the retina is applicable only for collimated laser radiation with specified divergence and is inapplicable for laser beams with unspecified geometrical parameters. The existence of biological uncertainties (spread of the characteristics of eyes) and, as a result, the necessity of using substantial safety factors when setting such standards, and also the lack of suitable methods of dosimetry often lead to unfounded overstatements of the danger level under highly diversified conditions of work involving laser radiation.

2. It is necessary to develop a unified standard-setting and dosimetry procedure which, along with adequate statistical material on biological and optical characteristics of the eyes, will make it possible to evaluate with concise, reliable probability the danger level in the presence of any laser radiation.

3. The suggested method of laser radiation dosimetry for the retina of the eye can serve as the basis for a laser radiation dosimetry procedure in the region of 0.4-1.2 μm.

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GEOPHYSICS, ASTRONOMY AND SPACE

'AIR & COSMOS' GIVES 'SALYUT-6' PROGRESS REPORT

Paris AIR & COSMOS in French 12 May 79 pp 46-47

[Article by Albert Ducrocq: "'Salyut-6': The Fourth Semester"]

[Text] From the moment when--despite emotions that the flight of "Soyuz-33" had given them--Rukavishnikov and Ivanov had returned safe and sound, some observers were surprised that the Soviets did not, almost right away, decided to send the two men or their back-up team aloft again on board a "Soyuz-34" space ship.

But this would be to forget that the purpose of a space mission is not only political. What is involved for the cosmonauts is to carry out a certain number of experiments up there, the scientific and technical program of the Bulgarians having been prepared with exceptional care because the operation was part of a series of events slated to celebrate the 1,000th anniversary of the Bulgarian state (established by Czar Samuel in 979), an anniversary that people planned to commemorate with great splash in Bulgaria as well as the Soviet Union. A special stamp had been issued on the occasion of the Soviet-Bulgarian flight.

But the experiments prepared by the Academy of Sciences of Bulgaria were located in the orbital compartment which burned up on the return of "Soyuz-33." One would image that several sets of the equipment had been assembled. The fact remains, however, that some time would be necessary to convert experimental equipment into flight models.

Another consideration could not fail to have an input.

Revamping of the Equipment

This is a general rule among the Soviets: When a piece of equipment is deficient its use is suspended, an investigation is opened, and the necessary modifications are made--all of this mandating a period which can range from a few weeks to several months. In the past the kind of accident that most closely resembled that which hit "Soyuz-33" was undoubtedly the one which occurred in 1965 with "Luna-6." At the time when the race between the United States and the USSR got under way as to who would be the first to land a camera on the surface of the moon, the Soviets had launched their "Luna" space vehicles at a rapid tempo. Their goal was the improvement of soft-landing techniques, the flight between the moon and the lunar field not seeming to pose problems for them. However, on "Luna-6" the engine which was supposed to correct the orbit malfunctioned. It was activated by remote control from the earth but it could not be turned off. So the "Luna" launchings were suspended for 4 months until the builders could be certain that such an accident would not occur again.

Likewise, it seems that on the morrow of the failure of "Soyuz-33" the decision was made to modify the principal engine so that in no case would this vital unit for the security of the cosmonauts experience a breakdown (the failures of "Soyuz-15," "Soyuz-23," and "Soyuz-25" were not apparently due to defects of the principal engine, every indication being that in all three cases the space ship had reached the immediate proximity of the space station where it was to dock). Indeed, it would not be possible to see it differently: Even if this was the first time that such a malfunction had occurred during a manned flight, the breakdown of the principal engine is an absolutely unacceptable contingency.

It would thus have been necessary for the Russians to suspend their program for the exploitation of "Salyut-6" were it not for the fact that the latter was in an active stage. We noted last week: The need to revamp a program while men were in orbit was an unprecedented event. Whereas Vladimir Layakhov and Valery Ryumin, on board the space vehicle since 27 February 1979, could be asked to wait a few weeks while the consequences of a change in mission were assessed--the time for a decision to be made regarding the fate of the "Salyut-6" space station--they could not be expected to hang on indefinitely considering the problems that would be raised for their subsistence as well as their return.

Diet of the Cosmonauts

Their subsistence involved first a problem of diet. Fifty days were to elapse without the crew receiving fresh food from the earth. Was it because these supplies were deemed useless, or because Lyakhov and Ryumin were shortly to come back to earth, or because, everything considered, the experts in space medicine approved the possibility of staggering the victuals?

It is undoubtedly not a coincidence that Soviet specialists in space medicine should have made a declaration on the diet of the cosmonauts as if to reassure us on their fate. Lyakhov and Ryumin are doing fine, the Russians told us. The two cosmonauts, as we already knew, were eating canned meat of a fairly conventional style, other food packed in aluminum tubes, but also dehydrated products.

The Soviets mentioned that because of the duration of the flight the calorie content of the crew's food rations was significantly increased. It was raised to 3,100 kilocalories a day. The cosmonauts were asked to balance their diet and to take pills of polyvitamins twice a day.

Apparently, food reserves were not short on board the space ship. Water was also available in sufficient quantity.

A water purifying system had nevertheless been conceived under the name of Priboy. The idea was ingenious: It consisted in recuperating the water vapor present in the space vehicle's atmosphere, notably because of the crew's perspiration. The cosmonauts had at first balked a little at drinking this water, but they were soon convinced that it did not have any particular taste. And the Priboy system became operational on "Salyut-6." But in the last analysis it does not seem that the alternative was very attractive: Fluctuations of the hygrometric level inside the space vehicle were minimal so that the amounts of water recuperated in this fashion were small (in the order of one liter a day) and the specialists wondered whether it was worth the effort--at least for existing flights, for in the case of missions far from the earth the ecological system would naturally be the rule--given that the "Progress" supply space ships could take to the crews all the water which they might need.

The cosmonauts divided each day as follows:

Nine hours to sleeping;

Two hours to meals, the four-meal-a-day arrangement having been approved;

Two-and-a-half hours to physical exercises;

One hour to miscellaneous projects including putting things in order and housekeeping chores; and

One-and-a-half hours to communications with the earth.

The Americans noted that new methods were introduced by the Russians enabling them to use coded transmissions. The cosmonauts can now communicate with their ground control center without the listening stations of other countries knowing what they are saying. Furthermore, the importance of the method used to insure communications links (space ships, "Molniya" satellites) makes it possible for communications to be established at any moment, the crew being freed from dependence on the period of radiovisibility from Soviet territory, hours around which they had earlier been obliged to organize their day. That, today, is the arrangement of the "set hours," organically much more productive, which was adopted and which calls for the cosmonauts' waking up at 0500 hours each day and their going to sleep at 2000 hours.

A 3-Year Program

We are wondering about the fate to be earmarked to "Salyut-6." The importance of this space station and the place that it holds in the Soviet space program have unquestionably been surprising. Everything seems to point to a plateau in that program.

Indeed, slightly less than 2 years had elapsed between the launchings of "Salyut-1" (19 April 1971) and "Salyut-2" (3 March 1973). This hiatus which had seemed long at the time was attributed to the entire restructuring of the "Soyuz" space craft and the orbital station following the decision not to have more than two cosmonauts man a "Soyuz" and, therefore, to redesign the "Salyut" for manning by only two space men.

This being so, starting with "Salyut-2"--which could not be manned by any crew and whose lifetime was extremely brief--the Soviets had accustomed us to the rate of the "Salyut" a year, 1974, 1975, and 1976 being marked by the operations of "Salyut-3," "Salyut-4," and "Salyut-5," respectively.

With "Salyut-6" we witnessed a break in this rate. The new space station whose launching had--we know now--been planned for the spring of 1977 was only put into orbit on 29 September 1977 and it is only in late 1977 that its exploitation could get underway and continue in 1978 and 1979 whereas the launching of "Salyut-7," announced for the end of 1978, was postponed from month to month.

In other words, the "Salyut-6" program will have covered 3 years and it seems that two circumstances explain this siution.

The first is unquestionably the very mission of "Salyut-6" which, in the Soviet space program, constitutes by all evidence the major stage in establishing a permanent orbital station, its planning and the existence of two docking units having given an entirely new scope to the experiment inasmuch as in 1-1/2 years no fewer than 12 space vehicles were able to come and dock with the vehicle and bring supplies of all kinds necessary for the pursuit of the exploitation of "Salyut-6."

But additionally another consideration certainly entered into account: The hesitation of the Soviets regarding the program to be assigned to "Salyut-7," a program which, in the past few semesters, seems to have been revamped on several occasions and which seems to have been changed very recently consequent on the failure of "Soyuz-33."

Wear and Tear on the Equipment

Thus, at the present time "Salyut-6" has been used in space for 2 years during which time it has been manned by crews for longer than 10 months already.

The space station has experienced wear and tear because of such use. That was anticipated, and the study of its wear and tear was undoubtedly the first goal of the Lyakhov and Ryumin mission. The situation seems to be as follows:

1. For a long time now no further reference is made in Soviet accounts to the large BST-1 telescope equipped with a 1.5-meter mirror one of whose

characteristics, it is known, is to operate in the remote infrared spectrum, both to survey the thermal features of the earth and also to identify the "warm bodies" of the universe, in this case stars having surface termperatures of some 1,000 degrees Centigrade which cannot be located by conventional methods and which are presumed to exist in large number. This BST-1 telescope required that its detection cell (using indium antimony) be kept at minus 270 degrees Centigrade. It is thought that once the supply of liquid helium was exhausted the cryostat was not recharged.

2. The orbit control system having been disconnected by the second maintenance crew, it was put back into service and has apparently been operating normally thanks to "Cascade" and "Delta" equipment and secondary propellants. As for the principal system, despite its repair by Lyakhov and Ryumin it seems not to have been turned on again, the Soviets having decided to use "Soyuz" and "Progress" space vehicles for important changes in the orbit of "Salyut-6."

3. The electrical installation has caused some concern to the Soviets. The photo-cells of three panels seem to have retained their approximate performance levels. In contrast, the accumulators were fatigued by the cycle of charging and discharging.

Among the replacement equipment ferried by the "Progress" space ships were filters and regenerators so that the air-conditioning system on "Salyut-6" is apparently continuing to function satisfactorily.

And we know that the last "Progress" space ship brought to Lyakhov and Ryumin a replacement oven--Krystal-3--which took the place of Krystal-2. It is thanks to Krystal-3 that some of the French ELMA experiments were carried out and undoubtedly this Krystal-3 oven would have found extensive use together with the Bulgarian models both during and after the space flight of Rukauishnikov and Ivanov if the "Soyuz-33" program had taken place as anticipated. That is another aspect of the failure of the mission: It led to a certain degree of nonuse of Krystal-3.

However, the cosmonauts were obviously not satisifed with remaining on board "Salyut-6" with their arms folded during the time when they should have been receiving Rukavishnikov and Ivanov. Starting on 13 April 1979 they got back to work, using the Splav oven--still in service--to undertake a metallurgical experiment. And so that the space station might not be disturbed by any bothersome gravity, the back engines were turned off and the space station was allowed to operate under free flight conditions.

Unit When?

The Soviets note that inside "Salyut" the temperature is 22 degrees Centigrade and the pressure stands at 770 mm of mercury. All is well.

The fact remains that the time allocated to maintenance chores seems to be long. This is so very simply because at the present time Lyakhov and Ryumin are using an old space station. It is remarkable that after covering some 400 million km around the earth, "Salyut-6" should still be livable, but one must not conceal the fact that this calls for a growing effort. We wish to say that the maintenance crew has to devote more and more time to the checking and repair of the space station. But that is one of the aspects of the mission: To tell the builders when the output of the crew will be nil because it will have to devote nearly all its time to the reconditioning of the various systems.

But we have not reached that point yet. And it is still impossible to say how far the Soviets will want to go.

Perhaps they should be prudent.

"Salyut-6" continues to offer all safety to its passengers but undoubtedly it is necessary to compare a space ship to an automobile which has many miles on its odometer. It is still running smoothly but when it breaks down it will happen all at once.

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GEOPHYSICS, ASTRONOMY AND SPACE

USSR DEVELOPS 'MINI' - TRANSPORT SHIP

Paris AIR ET COSMOS in French No 767, 26 May 79 p 66

[Article by Pierre Langereux: "The USSR Is Studying a "Mini-Transport Ship"]

[Text] The USSR is currently developing a "mini space transport ship" which is comparable to the French "Hermes" manned hypersonic glider, according to a CNES representative.

The basic concept of this Soviet "mini transport ship" is to carry 5 to 6 cosmonauts--or the equivalent in cargo--to visit and resupply orbital stations. Like "Hermes," it is a hypersonic vehicle that will make a horizontal reentry through the atmosphere (on automatic pilot) and will be launched by a classical expendable Soviet rocket. The concept of the Soviet "mini transport ship" is, therefore, very close to that of CNES. It is, however, a very different concept from that of the American Space Shuttle, which is a much larger and reusable vehicle that is destined to replace the classical American launcher.

According to French specialists, not until after 1990 does the USSR expect to develop an entirely reusable "space ship" like NASA's Space Shuttle.

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GEOPHYSICS, ASTRONOMY AND SPACE

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SPACE ENGINEERING IN THE SERVICE OF GEODETICS, CARTOGRAPHY AND NATURAL SCIENCE

Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 3, 1979 pp 26-32

[Article by Yu. Kiyenko and A. V. Filipchenko]

[Text] The decree "On the Establishment of the Higher Geodetic Administration," signed by V. I. Lenin 60 years ago established the basis for the rapid development of topographic-geodetic and cartographic work in our country in the interests of inspiring the productive forces, progress in the economy, and strengthening of the defensive capacity of the Soviet government.

In past years the selfless labor of the geodetics experts, the topographers and cartographers has provided for the construction of astronomical-geodetic networks which are unprecedented with respect to size and accuracy, the solution of the basic scientific problems with respect to determining the shape and size of the earth, the creation of different maps for the territory of the USSR occupying one sixth of the dry land of the planet.

As a result of the constant concern of our party and the Soviet government, the scientific and technical base of the geodetic and cartographic service has been persistently developed and improved. The highly productive methods and technical means based on using the latest achievements of physics, chemistry, mathematics, aviation, radioelectronics and computer engineering have come to replace the low-efficiency plane tablings, the tedious base and triangulation measurements.

Today, space engineering is playing a larger and larger role in geodetic and cartographic work. The use of artificial earth satellites has made it possible to solve a number of problems of cartographic-geodetic support of different branches of the national economy most efficiently.

Space engineering is being successfully used for the development of geodetic networks in enormous spaces, determination of the coordinates of the points of the earth's surface, more precise definition of the shape and size of the earth and planets of the solar system and also for cartographic study of our planet, the Moon, Venus, Mars and the investigation of natural wealth.

It is also necessary to note that in turn without cartographic-geodetic support it is impossible to realize the number of steps in space flight: the launching of artificial earth satellites into given orbits, the docking of spacecraft, the calculation of the flight path to the planets, the landing of spacecrafts in given areas on the earth and on the surface of the planets, the movement of automatic stations over the Moon, and so on. On the basis of the achievements in astronautics, aerial photography and cartography, a new area has been formed in the study of natural resources--space natural science.

In accordance with the resolutions of the 24th and 25th Congresses of the CPSU, a complex program is being realized in the Soviet Union for the use of space engineering for remote sounding of the earth in order to study its natural resources and environment. In accordance with this program, when performing experimental and production operations, various types of remote sounding are used--photographic and television surveys from manned and automatic spacecraft--and visual observations are made from onboard orbital stations.

The flight of the first earth astronaut Yu. A. Gagarin went down in history not only as the opening of the era of direct conquest of space by man, but also as the beginning of the age of studies of our planet from orbital altitudes. Yuriy Alekseyevich Gagarin noted that the shores of the continents, the islands, large rivers, large bodies of water, folds in the terrain are clearly obvious from spaceflight altitudes and it is even possible to distinguish a plowed field from a meadow. These first observations from onboard a spacecraft have confirmed the embryonic ideas of space natural science, a contribution to which has been made in practice by all manned flights.

In August 1961, the USSR astronaut G. S. Titov photographed the earth from space for the first time from onboard the Vostok-2 spacecraft. Since that time, the methods and means of obtaining information about the earth from space have improved from flight to flight, including the information for cartography. With insertion of the multipurpose Soyuz spacecraft (Figure 1) and the orbital stations of the Salyut type into near-earth orbit, the studies of our planet became multileveled and many sided.

Many prominent government workers, organizers of science and production, scientists, astronauts, collectives of scientific-research and production associations have made a large contribution to the development of the space area of earth science, the remote study of natural resources and the environment.

Let us discuss some results of the operations with respect to the remote sounding of the earth performed during the space flights.

From onboard the Soyuz-9 spacecraft in June 1970, USSR astronauts A. G. Nikolayev and V. I. Sevast'yanov performed surveys of the Caucasus, Central Asia, the Caspian Sea, Western Uspyurt, and so on. In this flight the subsatellite experiments were first performed in order to develop procedures for decoding space photographs. Space photographic maps on a 1:1,000,000 scale were compiled for the first time by the pictures from Soyuz-9 by the specialists of the Main Administration of Geodetics and Cartography, and the basic elements of the general geographic maps were updated for the Caspian area. In particular, it was established that the surface area of the Kara-Bogaz-Gol Gulf decreased by 7,000 km^2 in the decade preceding the flight.

The flight of the Soyuz-12 spacecraft was an important step in the development of natural science and cartography. A special camera for multizonal surveying was installed on the Soyuz-12 for the first time. USSR astronauts V. G. Lazarev and O. G. Makarov performed a significant volume of surveys in six and nine zones of the electromagnetic radiation spectrum. This flight demonstrated the efficiency of multizonal sounding for purposes of cartography, geological studies, a study of vegetation, soil, marine mammals, the decoding of natural formations with respect to their spectral reflectivity. As a result of the decoding of multizonal photographs for Soyuz-12, the experimental complex cartography was realized for the first time, oil and gas bearing structures, previously unknown faults in the earth's crust, and desert territories with shallow occurring fresh ground water previously unknown were detected.

The Salyut-1 orbital station was equipped with different equipment for photographing the earth, including wide-format equipment with a frame opening size of 180x180 mm.

The photographs of different scale taken by the crew made up of G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev made it possible to draw a conclusion regarding the expediency of the use of the set of survey materials with different parameters for natural science (scale, resolution in the terrain, and so on), and more precisely to define the significance of the effect of optical generalization for the decoding of the natural objects of different size spectral characteristics.

Later the flight programs of all the Soviet manned spacecraft and orbital stations provided taking surveys both for experimental and applied purposes. These surveys were successfully used for the solution of important national economic problems. For example, by the photographs received from Salyut-3 P. R. Popovich and Yu. P. Artyukhin defined 67 oil and gas bearing structures in one of the districts of the USSR, including underwater structures, and a number of intersections of large faults which are prospective in the exploration of valuable minerals.

Figure 1. Soyuz spacecraft in orbit.

On the Salyut-4 orbital station there were 12 photographic systems of different types--stationary, portable, multizonal, wide-format and small-frame. Special space cameras operated on this station: the KATE-140 developed at the TsNIIGAiK Institute, the FMS, and so on. On the basis of analyzing the multizonal surveys in our country performed using the FMS by two expeditions on the Salyut-4, important scientific generalizations were made which were later used as the basis for the development of the MKF-6 camera and other multizonal photographic systems for spacecraft. A large volume of surveys for production needs were performed by the wide-format KATE-140 multipurpose camera. This high-precision automatic topographic camera has an objective with a focal length of 140 mm and frame format of 180x180 mm. Around the perimeter of the frame there are special optical devices recording the coordinates of the center of the photograph and making it possible to consider the deformation of the light-sensitive material used.

The KATE-140 command instrument permits any possible surveying intervals to be given. On one photograph obtained by this camera, about 200,000 km^2 of the earth's surface are depicted. A multizonal and different-scale survey from the Salyut-4 opened up about 4.5 million km^2 of the southern part of our country. On the basis of this survey, a number of regional photographic maps were created encompassing the territories of the Northern Caspian Area, Kirgizia, Tadzhikistan, the Crimean Peninsula, Kalmytskaya ASSR, and so on.

Figure 2. Synthesized image of the vicinity of the Bukhtarminskoye Reservoir according to the survey materials from Soyuz-22.

Astronauts B. V. Volynov, V. M. Zholobov, V. V. Gorbatko and Yu. N. Glazkov performed complex observations of natural formations onboard the Salyut-5 orbital station along with the photographic survey which has become traditional, using optical viewers for this purpose. Experience has shown that the observations of the astronauts of fast natural processes and elemental phenomena combined with surveying provide valuable material for monitoring the state of the environment.

A flight for multizonal surveying of the earth's surface was made on the Soyuz-22 spacecraft. The crew made up of V. F. Bykovskiy and V. V. Aksenov delivered several thousand images of the dry land and water surface in six spectral ranges to the earth. For the survey, the MKF-6 camera was used which was developed jointly by specialists of the USSR and the GDR and was manufactured at the Karl Zeiss Jena National Enterprise. The MKF-6 makes it possible to obtain information in the wavelength band of 0.46-0.89 microns. This is achieved by using narrow-band light filters in front of the lenses. The passbands of the light filters do not overlap, and the camera shutters operate synchronously. The frame opening is 81x56 mm, and from an altitude of 250 km an image of the earth's surface about 19,000 km^2 in area is recorded on each photograph. The materials of the survey from the Soyuz-12 (Figure 2) are used by many organizations in our country and the German Democratic Republic. The maps for different purposes (Figures 3 and 4) were compiled by these photographs, and studies are made of the minerals, agriculture, forestry, the ocean, and so on.

The program for planned operations with respect to remote sounding of the earth has continued successfully onboard the Salyut-6 orbital station. This program was written by order of many of the branch organizations. It provides for the performance of surveys by the KATE-140, MKF-6 stationary cameras and a portable camera, and significant volume of visual observations were made (see Figure 5). The first two basic expeditions made up of Yu. V. Romanenko and G. M. Grechko (96 days), V. V. Kovalenko and A. S. Ivanchenko (140 days) and also the expeditions with the participation of astronauts V. A. Dzhanibekov, O. G. Makarov, A. A. Gubarev, V. Remek (Czechoslovakia), P. I. Klimuk, M. Germashevskiy (Poland), V. F. Bykovskiy, Z. Jena (German Democratic Republic) (see Figure 6) worked successfully on board the Salyut-6. During the operation of the station in the indicated period about 28,000 frames were taken up by the different cameras on different films in the various spectral zones.

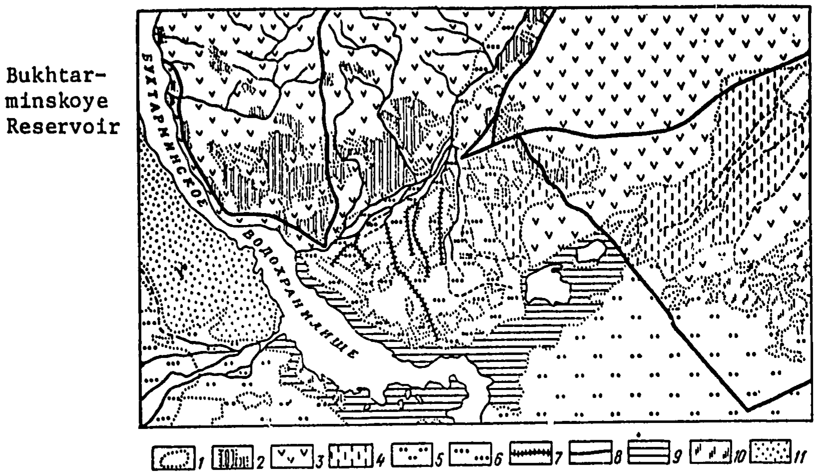

Figure 3. Schematic of the decoding of the use of land: 1--Irrigated plowed field; 2--Unirrigated plowed fields; 3--Mountain pasture; 4--Foothill pasture; 5--Plains pasture; 6--Pasture in the flood plains of the rivers; 7--Irrigation canal; 8--Roads; 9--Unused ground (barren but suitable for working); 10--Solonchaks; 11--Sand massifs

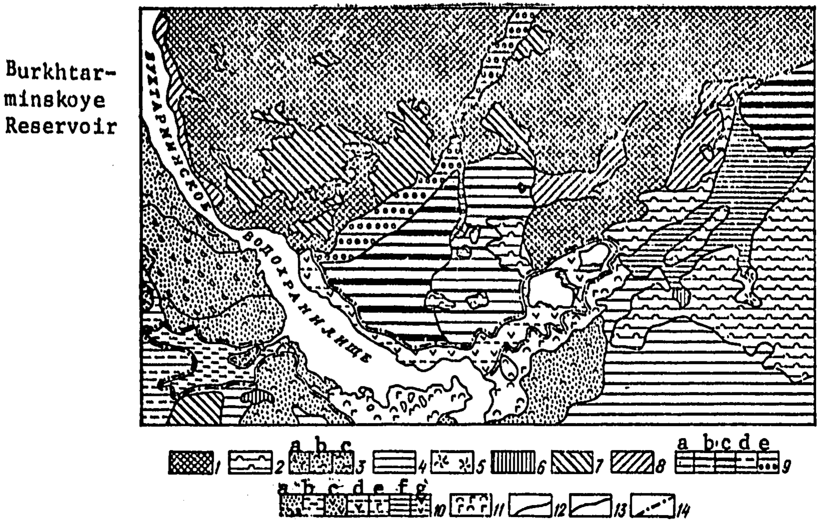

Figure 4. Schematic of landscape decoding. 1--Mountain landscapes (low mountains and area of low, rounded, isolated hills, steppe grass and brush); 2-9--Plains landscapes; 2--Semiarid hilly argellacious plains; 3--Steppe and desert aeolian sandy plains (a--unretained barkhans, b--hilly semiretained, c--gentle uneven retained, plowed in places); 4--Terraced flat dry-steppe plains; 5--Pakyrs [clay-surfaced desert]; 6--Swollen and wet solonchaks; 7--Gently waving foothill and intermontane steppe type plains, basically plowed up; 8--Foothills, inclined dry-steppe stony plains; 9--Gently sloping flat plains (a--semiarid, b--plowed with fragments of dry steppes, c--plowed with fragments of meadows, d--wet grassy meadow and marshy, e--flood plain meadow forest lands covered with undergrowth); 10-11--Landscapes of the zone of influence of the Bukhtarminskoye Reservoir; 10--Slightly inclined surfaces of the drained bottom (a--sandy, free of vegetation, b--silty-sandy, free of vegetation, c--sandy with vegetating hydrophytes, d--silty-sandy with vegetating hydrophytes, e--silty-sandy with drying hydrophytes, f--silty loamy with bottom vegetation, g--silty-loamy with vegetating hydrophytes); 11--Hilly sand with drying hydrophytes in the low places and steppe vegetation on the hills; 12--Landscape boundaries; 13--Lake and reservoir boundaries; 14--Line of maximum level of the Bukhtarminskoye Reservoir.

Figure 5. Photograph of sweeps of forest fires from the Salyut-6 orbital station.

On 11 and 26 September 1978, the KATE-140 camera made a coherent survey for the first time--it photographed the given territory from different orbital points. The purpose of this experiment was to study the possibilities of improving the accuracy of determining the relative and absolute altitudes of the points on the terrain by the results of measurements on the space photographs with optimal angle of photogrametric location. This problem is of interest for the creation of the high altitude part of the topographic maps and for the photogrametric clustering of the reference geodetic networks over large areas. Scientific-procedural and applied problems of the participation of astronauts in monitoring the state of the environment have been worked out on the Salyut-6. The astronauts performed successful observations of the volcanic activity, the movement of icebergs in the oceans, the spread of the muddy debris cones of the rivers into the seas, the dynamics of dust storms, the occurrence of forest fires, and so on.

The observations of marine currents and surveying of them to create hydrographic maps are highly interesting. It turned out that the currents and eddies which are not visible from the aircraft and for the detection of which from ships large expenditures of time and means are required can not only be traced from space, but they can also be recorded on special photographic receivers. The possibility of a survey of the underwater relief of the shelf shoals has also been established.

The significance of the results of these experiments is difficult to overestimate. They are important for cartography, marine hydrophysics, climatology, the fishing industry, the exploration of minerals on the shelf, and so on. All of the information received from space is placed at the disposal of the specialists in the different branches of the national economy.

After preliminary development on manned spacecraft, many problems are solved by space robots, automatic unmanned spacecraft. It must be noted that today there are many natural scientific and cartographic problems that are being solved by automated artifical earth satellites. Observations are constantly made from the Meteor type artificial earth satellites used by the weather service.

The multizonal surveys from space to study natural objects and the environment are made from the Kosmos series satellites. For example, a survey from the Kosmos-1033 satellite provided an enormous amount of information for cartography and studies of the natural resources of our country. It was calculated (Academician Ye. K. Fedorov) that in our country alone, the cost benefit from the application of space information in the solution of hydrometeorological problems amounts to more than 900 million rubles. By the estimates of the foreign specialists, the use of the remote sounding data of the earth from space on a global scale will in the future give a significant cost benefit. The expenditures on the development of astronautics are justified.

The surveying of earth from space for cartographic purposes has a number of valuable peculiarities and advantages over the traditional methods of the creation and revision of maps for various purposes. One of these peculiarities is that space video information is multipurpose and interbranch. On the basis of it, geographic maps can be created along with maps which characterize the condition of the agricultural lands and the forests, the study of minerals, the location of shoals in the seas and oceans, ocean currents, the dynamics of natural processes, and so. This means that a space photograph is a united base, a technical base for the interpretation and mapping of various natural objects, processes and phenomena in their natural interrelation. The indicated fact opens up broad prospects for complex mapping of territories with the creation of mutually coordinated maps with different aspect content. As was noted above, this type of work has been started from the Soyuz-12 survey data.

At the present time the operations with respect to complex cartography have already gone beyond the scope of experimentation. On the basis of the information obtained both from manned and automatic objects, complexes of cartographic documents classifying broad spaces have been created. Such documents make it possible to estimate the natural potential of large economic regions and territories for prospective exploitation.

Let us present the following example. A landslide covering the Murgab River occurred in 1911 in the mountains of Pamir as a result of an earthquake. The slide rock about 700 meters high formed Sarezskoye Lake which contains about 19 km^3 of fresh water. It was necessary to develop a comprehensive solution to the problem of the Sarezskoye Lake. A study was made of various means of using the water of Sarezskoye Lake: discharge of it into the Aral Sea to restore the disturbed water balance, the construction of a hydroelectric power plant on the natural dam to irrigate the irrigated farmlands, and so on.

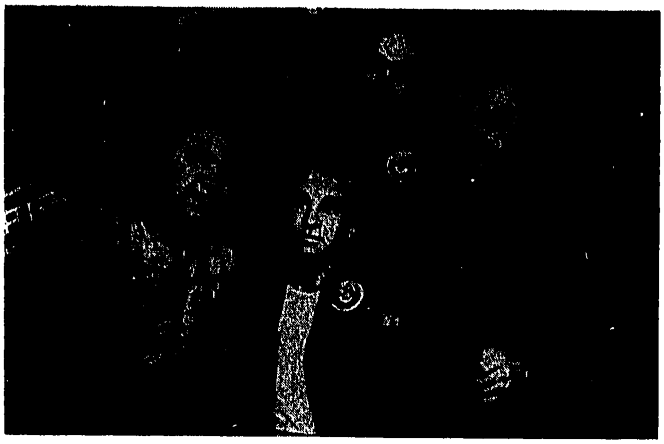

Figure 6. USSR astronauts (left to right): G. M. Grechko, O. G. Makarov, V. A. Dzhanibekov, Yu. V. Romanenko.

In order to prepare design solutions, complex information on the Sarezskoye region was needed. For this purpose, on the basis of the space surveys a series of thematic maps were created. They characterized the engineering-geological conditions, the soil, the quaternary deposits, tectonics, seismic and avalanche danger, vegetative cover, and so on. The time required to create such maps under the conditions of the most difficult transport access by comparison with ordinary methods of operations was reduced by five times, and the expenditures of means was reduced by 15 times. There are many such examples of the complex use of space sounding data.

The success of the application of space surveys for cartography arises from the following peculiarities of them. None of the other methods of obtaining information provides a territorial survey of the type that a spacecraft survey offers. For example, from an orbital station the KATE-140 photographs a path 450 km wide. Accordingly, for small-scale cartography there is no necessity for processing thousands of photographs, and this increases the productivity of labor by many times.

Using a multizonal survey and selecting the images in defined zones of the spectrum, the map makers essentially realize the process of automatic selection of the necessary information which is at the very essence of this survey. Thus, in the visible part of the spectrum the relief of the shoals is depicted; in the near infrared band, the effect of the vegetative cover on the formation of the image of the terrain is attenuated, but the structure of the surface, traces of erosion, and the hydrographic network are clearly recorded; on the spectral zonal photographs the images of the nonuniform forests, farmlands, rock, and so on are distinguished by various colors.

For optical generalization of information, a different scale survey is used. With a decrease in scale and resolution in the terrain, small objects disappear, but at the same time general laws appear; large objects are easily decoded. The indicated peculiarity leads to a type of automation of the process selecting the required cartographic information influencing the acceleration of the process of creating maps and improving the quality.

The speed of the spacecraft of about 8 km/sec makes it possible to survey large territories in a short time interval. Consequently, images of vast areas are obtained under identical conditions, and like objects, with identical decoding attributes. This permits broad application of the method of analogy, automation of the decoding process on the basis of using optoelectronic systems, improvement of the productivity labor, and a reduction of the expenditures of time on cartographic interpretation.

Geometric characteristics of space photographs also promote simplification of the cartographic processing of the images. When surveying from orbit, the central projection will become close to orthogonal, the effect of the errors caused by the relief is attenuated, and this means that there is no necessity for tedious transformation by zones.

Without discussing the other advantages of the use of space information for cartographic operations, let us only note one, theoretically important one. With the required organization of the remote sounding system, the data on the section of the terrain can be obtained with given periodicity at any time of year or day. A comparison of the images from different times, of the multiple use of the photographs will permit not only updating of the maps, but also discovery of the dynamics of the natural environment, variations in time of the objects, processes and phenomena. This remote sounding system must become the base for the development of new area of cartography--space dynamic cartography.

It appears expedient to develop dynamic cartography in the GUGK [Main Administration of Geodetics and Cartography] system. To a defined degree such work has also been performed by the Geodetic and Cartographic Service as a map revision process. However, none of the departments of the country has as yet or is performing a complex scientific generalization of the variations in the terrain, although the time for this has come. Under the conditions of fast development of engineering, the intervention of man in nature has become commensurate with the large-scale natural processes. Billions of tons of minerals have been extracted from the depths of the earth; artificial reservoirs have been created, and the steppes have been converted to granaries, the deserts have been transformed in oases, cities have sprung in the taiga and tundra, oil and gas lines, railroads, and so on have been laid. As a result, the appearance of the environment, its climate, soil, vegetations, relierf, and so on change. Here it is impossible to forget about the effect on the environment of the constantly operating natural processes, for example, tectonic, relief forming, hydraulic.

The Communist Party of the Soviet Union is showing great concern for environmental protection, the conservation and reproduction of the natural wealth. The 25th Congress of the CPSU indicated the urgency of this problem.

It is important to organize the cartographic duty service, a service for dynamic mapping of slowly occurring natural processes. The technical base for the solution of such problems can become the space information. It is expedient to carry out planned dynamic cartography basically on a 1:500,000 scale over the territory of the entire country, and on scales of 1:1,000,000 and 1:200,000 for the individual areas. On the first level it is necessary to create inventory maps of recording the modern state of the natural environment, then after given time intervals to produce dynamic and forecasting maps. The forecasting maps can be an important source of information for the agencies for governmental control of the national economy. At the present time space engineering is opening up new possibilities in the field of the progress of earth sciences.

The 60th anniversary of the decree creating the State Geodetic and Cartographic Service of the country is being met by topographers, geodetics experts, topographs and photogrametric experts with great achievements, among which is the assimilation of the space data about the earth and natural resources. Today specialized subdivisions of the Main Administration of Geodetics and Cartography are successfully conducting interbranch processing of space data, supplying more than 400 scientific, planning and research and production organizations of the country with it. There are many unresolved problems in space cartography and natural science. These include the problems of the creation of new means of sounding, the interbranch processing, interpretation of space surveys, acceleration of the introduction of the latest methods of working with the use of the space survey materials into the national economy. There is no doubt that all of this will be accomplished by the developers of the geodetic and cartographic service interacting with other branches of the national economy of our country.

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GEOPHYSICS, ASTRONOMY AND SPACE

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ASTRONOMICAL, GEODETIC NETWORK OF THE USSR

Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 3, 1979 pp 32-35

[Article by A. Z. Sazonov]

[Text] The creation of the astronomical-geodetics network of the USSR is the most important result of the 60 years of activity of the State Geodetic Service. The triangulation and polygonometric points, classes 1 and 2, placed throughout the entire territory of the country, together with the points of the concentration network serve as the reference geodetic base not only for topographic and cartographic operations, but also many others connected with the study and economic exploitation of the earth. In order to construct the astronomical-geodetic network of the USSR, it was necessary to carry out a large program of scientific studies, to solve complex technical and organizational problems of support and performance of mass high-precision measurements in an area of more than 20,000,000 square kilometers with a great variety of climatic and physical-geographic conditions.

The growth and development of this work are closely connected with the social transformation of our country and socialist construction developed after the Great October Socialist Revolution. According to the exact words of F. N. Krasovskiy: "...in the sphere of geodetics, topography and cartography the Great October Revolution gave rise to an enormous demand and teeming activity" (Selected Works, Vol II, Moscow, Geodezizdat, 1956, p 29). In March 1919, by the Lenin decree on the establishment of a higher geodetic administration, the geodetic and topographic work was transferred for the first time in the world to a civilian national organization. The work was defined as a national, nondepartmental matter. The creation of the national geodetic service indicated recognition of the necessity for the performance of all geodetic and topographic work in the country by a united plan taking into account the variety of requests by the entire rapidly developing socialist economy.

Before the revolution, the development of the reference geodetic networks was considered as an auxiliary temporary operation recognized as providing a given survey and losing its significance after completion. Therefore triangulation was constructed in isolated networks by guberniyas without

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a united plan or mutual relations. The geodetic stations defined as a result of precise measurements with large expenditures of labor were not reinforced by long term centers. This led to the loss of in practice all of the networks constructed before the revolution during the entire century history of triangulation work in Russia. The Soviet geodetics experts had to create the reference geodetic networks over again with complete understanding of the significance of the preceding work.

When stating the problem of developing the national geodetic network in a territory extending more than 170 degrees longitudinally and 40 degrees latitudinally, it was obvious that it could be solved only on a scientific basis and that in general this practical problem was not resolvable separately from the basic scientific problems of geodesy. Therefore with the first step, along with solving a large class of procedural, technical and organizational problems connected with the statement of the astronomical-geodetic operations in the country, fundamental research was developed with respect to the program problems of the construction and equalization of broad astronomical-geodetic networks and the theory of the geodetic study of the earth. The results of these operations advanced Soviet geodetic science and practice of constructing astronomical-geodetic nets to first place in the world.

The basic practical problem of creating the astronomical-geodetic network consists in the fact that a united coordinate system was extended in the shortest possible time to the entire territory of the country. For its solution in 1928 F. N. Krasovskiy developed an organized, scientifically substantiated program for the propagation of coordinates with respect to class 1 triangulation elements. The individual element is a chain of 16 to 20 triangles with a total extent of about 200 km. At the end of each link the bases are measured and the astronomical latitudes, longitudes and azimuths are determined to stations. The astronomical latitude and longitude are determines also at one of the stations in the middle of the link. This type of link is an independent astronomical-geodetic construction and in the presence of a gravimetric survey permits determination of the difference in the geodetic coordinates of the ends of the link in the selected system. The precision of the angular, linear and astronomical measurements and the length of the link are selected so that the transfer of geodetic coordinates along the link is made with a precision no less than 1:200,000. The links form closed polygons with a perimeter of 800-1,000 km. The network of polygons makes it possible to control the transfer of coordinates with respect to links and increase the precision of propagating the coordinates to great distances. For substantiation of detailed surveys the polygons were broken down into class 2 basic triangulation series, concentration series and nets.

This approach to the construction of the astronomical-geodetic net made it possible in 20 years or so to extend the united system of geodetic coordinates to all of the economically important regions of the European part of the USSR, Central Asia, Siberia and the Far East. In 1942-1945 the leveling of the 87 polygons of the astronomical-geodetic network of the USSR created at that time was performed, which was a valuable scientific-technical and practical achievement. The materials of the geodetic, astronomical and gravimetric measurements gathered by the well-thoughtout program were used to solve the problem of great state importance--establishment of the dimensions of the elipsoid most suitable for the earth's surface within the limits of our country; determination of the parameters of its orientation in the body of the earth, deviations of the plumb lines and altitudes of the quasigeoid including information about the configuration of the earth and required for projection of the measurements on an elipsoid; obtaining the coordinates of the points of the broad network from joint leveling. With respect to scales and statement, this leveling of the USSR government geodetic network remains unexcelled to the present time by any other country of the world.

At the beginning of the 1950's in connection with the transition to the large-scale cartography of the territory of the country, the necessity arose for further improvement of the program for the construction of the USSR astronomical-geodetic network. The class 1 triangulation polygons began to be filled with a continuous network of class 2 triangulation including the bases and astronomical latitudes, longitudes and azimuths defined by the class 1 program, that is, also the astronomical-geodetic network.

With transition to the new program for constructing the astronomical-geodetic network not only did the volume of highly precise operations increase sharply, but also their performance became more complicated inasmuch as in the case of solid triangulation it is not always possible to get around the sections that are difficult for performing operations as was done when projecting the class 1 triangulation links. The organization and the performance of the operations under complex conditions frequently required literally heroic efforts on the part of the geodetic experts, for example, when working in the marshy taiga of the Western Siberian lowland. The necessity and importance of this work later became clear to everyone in connection with the discovery of the oil fields. Now this is one of the most actively developing regions of the country and areas of topographic-geodetic operations.

The improvement of the program for constructing the astronomical-geodetic network was directed first of all at improving the precision of determining the mutual position of the stations adjacent to it at which the exact detailed surveys are based. However, a significant increase in the number of astronomical-geodetic measurements creates the possibility for improving the precision of the transfer of coordinates to greater distances although the conditions for realization of these possibilities have developed only in the last 15 to 20 years.

This period has become the most important in developing the astronomical-geodetic network of the country. During this period the construction of the greater part of the network and its partial leveling have been carried out. For this period high rates of operations, which have increased in spite of the gradual advancement into areas with difficult conditions for their performance, the creation and introduction of new equipment for high precision measurements, the broad utilization of modern computer engineering based on computers which has made it possible to deal with the enormous volume of mathematical processing of measurement results in the astronomical-geodetic network--all are characteristic of this period.

The leveling is done successively as the operations are completed, in large blocs. The actual precision with which the elements of the astronomical-geodetic network are measured obtained from analyzing the measurement materials and the leveling results corresponds to the plan. It ensures the possibility of determining the mutual position of adjacent stations at any location of the network with a precision no worse than 1:100,000 and transfer of the coordinates a distance of 8,000 to 9,000 km with a precision of 3-4 meters.

This possibility can be realized in the future by new general leveling of the astronomical-geodetic network as a single continuous triangulation network and classes 1 and 2 polygonometry. In the time since the beginning of the creation of the astronomical-geodetic network new information has appeared on the earth, its rotation parameters and the movement of the poles. The nature of the errors existing in the network have been studied better, the coordinates of the stars, the standards of length, time, and so on have been more precisely defined. With all of the thinking about the implemented program for establishment and propagation of the existing coordinate system, this knowledge could not be completely taken into account and has only found limited application. The presentation of the measurements in accordance with the new knowledge, joint use of these measurements in the leveling area also are creating a basic reserve for proving the accuracy of the available data.

The general leveling of the national geodetic network is a complex scientific and technical problem. For its solution it is necessary first of all to define the role and the nature of use in leveling of materials that are different with respect to time of the measurements performed by the geodetics experts, both classical and new. Up to now the object of the leveling was the results of the angular, linear, and azimuthal measurements. For the contemporary density of the astronomical stations, the geodetic and gravimetric measurements permit determination of the difference of the astronomical coordinates with a precision noticeably greater than the precision of determining this difference from the direct astronomical measurements. Inasmuch as the exact knowledge of the direction of the lines of force of the gravitational field of the earth at the geodetic network stations now is no less important than the knowledge of their exact position, the problem of the nature of the use of the materials of all the measurements in general leveling deserves special attention.

The basic complexity of solving the problem of new general leveling is the overall volume of processed information. It will be necessary to gather, prepare and input to the computer a minimun of 10^7 ten-bit numbers or the corresponding volume of symbolic data, compiled $2 \cdot 10^6$ error equations, compile and solve a system of normal equations with no less than $5 \cdot 10^6$ nonzero elements in the initial system and no less than $3 \cdot 10^8$ in the converted system. Even if we store only nonzero elements, which always lowers the efficiency, a thought structure of files and organization of the work with them ensuring fast information exchange, its appropriate storage and the possibility of fast recovery in the case of loss are required.

The method of leveling, in addition to the possibility of effective realization of it on the computer must ensure the discovery and elimination of measuring, information and computational errors in each calculation step and not on completion of the leveling, and also the possibility of estimating the accuracy of all of the leveled elements of the network of interest.

The realization of the general leveling program can take several years, but this work should not be considered as a one-time operation. Its results must not only permit us to obtain a new catalogue, fixing the age, but also be prevented so as to provide for rapid consideration of subsequent measurements connected with further improvement of the network and more precise knowledge about the earth, that is, the new catalogue must be dynamic. Modern computer engineering will permit us to organize the mathematical processing of the astronomical-geodetic network.

The prospects for further improvement of the network and supplementing it with new measurements are defined by its principal purpose--storage of the coordinate system of the country. For successful realization of this function it is necessary to consider the following factors: the possibility of loss of stations connected with the activity of man or the forces of nature (erosion, landslides, heaving, earthquakes, and so); "obsolescence" of the network in connection with increased requirements on the accuracy of its elements; variation of the coordinates of the network stations as a result of movements of the earth's crust.

The recovery of the lost stations presents no theoretical difficulties, for when using modern measurement means, this problem is solved quite simply by determining new stations by the retained or surrounding ones. This is a matter only of organizing the service for tracing and recovery of lost stations.

In order to prevent obsolescence of the network, it is now necessary to resort to the implementation of measures aimed at improving the accuracy of all of its elements. Here it is important not so much to determine certain unique superaccurate and superlong connections as to have planned, dense saturation of the network with new measurements, primarily linear measurements. It is easy to see that for the achieved accuracy of the measured angles by a reasonable increase in density of the linear measurements in the network alone it is possible to increase the accuracy of determining the mutual position of adjacent stations to 1:200,000 at the weakest point.

When constructing the astronomical-geodetic network the measurement of the lengths was the most difficult process. Therefore the bases in the network were placed as sparsely as possible, and the angles were measured more precisely in order to ensure reliable transfer of lengths. As a result, the accuracy of the mutual position of the adjacent stations is not determined by the density of the bases in the network. Now when an exact measurement of the lengths is made much more simply and much faster, it is necessary to use this reserve to improve the accuracy of the entire network.

It is also necessary to think through and implement a program for improving the accuracy of the astronomical definitions of latitudes, longitudes and azimuths in the network. This problem is much more complex because the labor consumption of the astronomical determinations has not decreased noticeably, in spite of the improvement of the methods and means of astronomical determinations. The concentration of astronomical determinations serves to increase the accuracy of determining the directions of the plumb lines, that is, the astronomical coordinates themselves.

The possibility of this was noted above as a result of the joint use of geodetic and gravimetric materials. The well-thoughtout program for concentration of astronomical determinations will permit efficient use of this important result of creating the astronomical-geodetic network.

For these purposes, it is necessary to make use of the possibilities which the high precision measurements of the zenith distances with the application of refractometers give. The reasonable combination of these measurements and concentration of astronomical stations can turn out to be the most effective.

In the networks of longer extent, it is possible to accumulate the systematic effect of certain factors which is not discovered in the errors in the provisional equations obtained by the results of the performed measurements. Therefore it appears expedient to determine the mutual position of a sparse network of special stations independently by theoretically different methods and means. For these purposes, it is most appropriate to use the observations of the artificial earth satellites. The achieved accuracy of determining the mutual position with respect to the satellites is now such that the observation stations can be placed at distances of no less than 1,000 km from each other. The network of such stations determined by the satellite observations and uniformly placed in the territory of the country will be a good control for the accuracy of transfer of the coordinates to great distances.

The discovery and consideration of the possible movements of different parts of the continent within the limits of our country obviously is a quite difficult, expensive part of the program for storing the coordinate system. It is possible to trace the displacement of large blocks of the earth's crust, using the methods of long-base radiointerferometry and laser location of the moon. The organization of this tracing is a long-term measure, and it must be started with careful selection of the locations of the minimum

(6 to 8) number of stations, changing the mutual position of which would characterize the movement of the blocks. The mutual position of these stations must be determined with maximum possible accuracy, using all of the latest means.

In order to discover the movements of a regional nature, it is necessary first of all to note the fault lines which can be the boundaries of the regions by the existing materials (the space photographs, geophysical data, and so on). The repetition of measurements in the triangles of the continuous network located along the planned lines will help make it possible to more precisely determine the effective boundaries of the moving sections and to organize the tracing of the movement along the boundaries of the regions.

Now in the world there are no geodetic networks compared with the astronomical-geodetic network of the USSR with respect to size, unity of the execution program and uniformity although a great deal of attention has been given to the creation of such networks also in other countries.

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GEOPHYSICS, ASTRONOMY AND SPACE

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MODERN PROBLEMS AND PROSPECTS FOR SATELLITE GEODETICS

Moscow GEODEZIYA I KARTOGRAFIYA in Russian No 3, 1979 pp 36-38

[Article by N. L. Makarenko]

[Text] In connection with using the observations of artificial earth satellites in geodetics, many complex problems have arisen, the solution of which has been worked on by the geodetics experts for two decades. These problems are connected both with the methods of observation and consistent use of them.

In the first step the basic method of satellite observation was photographing them against the background of the stars. The photographic method played a significant role in solving geodetic problems. Thanks to this method, a global geodetic system of coordinates was created in the first approximation, and the parameters of the earth's gravitational field were defined. Then the photographic observations gradually began to be replaced by laser and dopler observations as more accurate.

Let us note the basic factors limiting the accuracy of the photographic observations. First of all photography of both active and passive satellites is accomplished against a background of the stars and, consequently, the accuracy of the results obtained is limited to the accuracy of the stellar catalogue used. In order to lessen the errors caused by the optical system of the camera and the negative material, it is necessary to use catalogues with a large number of stars: about 6 to 8 per square degree. The creation of such catalogues, let us call them satellite catalogues, is a very tedious job; in addition, the accuracy of them decreases with time as a result of inexact knowledge of the natural movements of the stars. If we assume that on the average the accuracy of the coordinates of the stars of the satellite catalogue is 0.2-0.3", it is difficult to expect (with consideration of other error sources) that the actual accuracy of the directions of the terrestrial chords obtained by the results of photographic observations of artificial earth satellites will be higher than 1:1,000,000. Of course, this is high accuracy, but it technically can be realized for comparatively high satellites having low apparent velocity. However, these satellites are more advantageous (from the point of view of optimalness of configuration) to observe from stations located at great distances from each other, and then the error in the linear measurement corresponding to the presented angular measurement will become significant. Thus, when using the photographic method in the best case it is possible to achieve a mean square error determination of the coordinates of a ground station of 3 to 4 meters. Let us also note that the horizontal component of the directions of the terrestrial chords can be determined one and a half times more precisely than the vertical. However, this already pertains to the problem of the special use of the azimuthal components of the directions of the chords determined photographically.

What has been stated above does not mean that the photographic methods have lost their significance for satellite geodesy. It must be considered that up to the present time they are one of the basic means ensuring orientation of the cosmic triangulation networks in the coordinate system connected with the axis of rotation of the earth.

The application of laser range finders has sharply increased the accuracy of the satellite observations. The instrument accuracy of measuring the distances to the satellites on the order of 1-3 cm has been theoretically achievable. However, the error in the distance measured to a satellite by a laser as a result of inexact knowledge of the parameters of the actual atmosphere has been estimated at approximately 15 cm, and a decrease in it by several times is a difficult problem. Obviously, the accuracy of the laser measurements will be limited to the random variations of the index of refraction as a result of turbulence of the atmosphere which will introduce an error on the order of 1 cm.

In order to achieve high accuracy of measuring the distances by the laser range finders, high accuracy of determining the universal time UT-1, defining the rotation of the earth in the inertial space and the observation time (or in the special case of synchronization of the observations) is required. In order not to lower the accuracy of determining the geodetic parameters when using laser range finders having an accuracy of 1-2 dm, the UT-1 time must be determined with a precision of ~0.3 milliseconds, and the observation time with an accuracy of several hundreds of milliseconds.

The methods of geodetic use of the results of the high-precision laser measurements must be carefully developed. This is connected with the fact that in the cosmic geometric methods when using laser measurements combined with photographic observations a sharp increase in the accuracy of the former does not lead to a significant increase in accuracy of determining the elements of the ground constructions.

When using only linear measurements in the geometric method, difficulties are also encountered. Thus, the coefficient of reduction in the accuracy of determining the coordinates of the stations of the regional networks in this case is approximately 10. In all probability, the use of the high-precision laser measurements is most effective in the orbital method. Here the proposition of L. Stange (German Democratic Republic) and K. Swiatek (Polish Peoples Republic) on the use of the calculated distance between the positions of the artificial earth satellites together with the distances to them measured synchronously by laser range finders is prospective. The relative distance on the orbit, as the experimental calculations have demonstrated, can be obtained under defined conditions with an accuracy corresponding to the laser measurements.

The optical methods of observing the satellites depend completely on the weather conditions. Here the equipment used is awkward and poorly transportable. For these reasons, the photographic and laser methods are basically used under stationary conditions.

A special place in satellite geodesy has been occupied in the last decade by radio technical methods of observation, in particular, dopler. They are easily subjected to automation, they do not depend in practice on the weather conditions, the equipment used in them is small and portable. As a result of the dopler measurements it is possible to obtain both the radial velocity of the satellite (the differential method) and the difference in distances to its two positions in a defined time interval (the integral method). In practice the radial velocity is defined as the ratio of the difference in distances to the two positions of the artificial earth satellites (this difference is directly proportional to the number of accumulated dopler cycles) to the time interval in which it was obtained. This time interval must be sufficiently small (as a result of the curvature of the orbit) so that the radial velocity obtained pertains directly to the satellite and not to a fictitious point close to the satellite.

Theoretically, the measurements of the radial velocity give more geodetic information than the measurements of the differences in distances. If we assume the coordinates of the artificial earth satellites to be known, the differential integral methods will become equivalent. From the practical point of view, the integral method has indisputable advantages over the differential method, for it permits a sharp "compression" of the volume of measured information and automatic averaging of certain types of errors. The integration interval is selected considering the above-mentioned factors and also the possible losses of larger integration intervals of the doppler cycles for technical reasons.

The precision of the doppler measurements will depend on the carefulness of consideration of the influence on them of the troposphere and the ionosphere and also the instrument accuracy. Obviously, the difference in distances to artificial earth satellites in a time interval on the order of one minute prospectively can be measured by the doppler method with an accuracy of several centimeters.

Further progress in the area of using radio technical methods in satellite geodetics is connected with the development of time storage equipment. If the satellites and observation stations are equipped with highly precise time standards, it will be possible to make direct measurements of the distances between them, determining the delay time of the satellite-station signal propagation. The frequency generators with instability of 10^{-13} per day will permit us to obtain distances with an error of 1-2 meters in a half-day interval.

Let us consider the paths of geodetic utilization of the results of the satellite observations basically from the point of view of their production application. Of course, any new result in qualitative or quantitative respects in satellite geodetics is a scientific achievement. In the final analysis it is not so important which methods or technical means were used to obtain it. It is another matter to obtain production results; each new method must be technically and economically effective.

It is already clear now that the satellite methods will find broad application when determining the coordinates of the geodetic stations. Here an increase in accuracy will be accompanied by an increase in the volumes of use of satellite means and greater variety of types of operations. The accuracy of determining the coordinates on the order of 5 meters is sufficient for the monitoring and more precise determination of the broad continental astronomical-geodetic networks and coordination of the remote islands. On achievement of accuracy of 1 meter, a geodetic base can be created with distances between stations of about 200 km for any territory. Here it must be noted that the satellite orbital methods will permit determination of the coordinates of the stations independently of each other (that is, without successive transfer of coordinates) and, consequently, without loss of accuracy on going away from the initial station in contrast to the ordinary geodetic method.

Further improvement of the accuracy of the satellite method is most realistic when using the translocation method where certain sections of the orbits of the artificial earth satellites are observed. In this case the mutual position of the stations can be determined with an accuracy of 0.1 to 0.3 meters and obviously then the satellite methods will be able to replace the traditional methods of development of the triangulations of all classes. Of course, with consideration of their economic expediency the new methods will find broad application when solving geodetic problems and in other branches of the national economy.

What will the future equipment and satellite methods of coordinate determination be like? First of all the equipment must be easily portable (weighing several tens of kilograms), rapidly deployable (in a few minutes), all weather, in practice completely automated, operating on a real time scale. The work with the equipment will consist in setting it up at the station, switching it on and obtaining the coordinates directly in the given form. The results will be consistently improved with an increase in observation time.

Let us note that the stated goals can be achieved by the application of radio technical methods of satellite observation (doppler and long range). Here the primary difficulty is achievement of the accuracy of the satellite systems required for production purposes. In our opinion, the satellite methods of determination of the coordinates will develop in three basic directions.

The first direction is connected with the application of the navigational-geodetic version of the satellite systems. The satellite is observed from the reference stations, and its orbit is calculated by these observations. Then the coordinates of the artificial earth satellites are predicted for some time in the future, and they are transmitted onboard the satellite, and then during the measurement process they are transmitted to the defined station and are used together with the measurements to determine its position. This path requires highly accurate prediction of the movement of the satellite for which it is necessary to know the disturbing forces acting on the satellites well and, above all, the gravitational field of the earth. Increasing the altitude of the satellite, it is possible to decrease the effect of the earth's gravitational forces and the atmosphere and more precisely to define the prediction, but it is still not possible to completely solve the problem of forecasting with the required accuracy for the geodetic experts. Therefore in practice the geodetic version of these satellite systems is also used. It consists in the fact that in order to determine the coordinates of the station it is not the predicted satellite coordinates that are used, but ones calculated by the observations already performed from the reference stations. This method permits us to reduce the effect of the inaccuracy of the parameters of the model of the disturbing forces to a minimum, and then the accuracy of the calculated orbit of the satellite will basically depend on the accuracy of the measurements and the geometric factors. However, the method of determining the coordinates in the given case is insufficiently operative and automated.

The rapid development of computer engineering will in the near future permit realization of the following version of the satellite system.

On board the satellite a quite powerful computer system has been installed which processes the measurement results from the satellite to the reference stations as they are performed for successive calculation of its coordinates and more precise determination of them. The coordinates obtained (just as in the navigational-geodetic version) together with the results of the measurements from a defined station are then used for calculation of its position. In the investigated case with a sufficient number of reference stations the prediction time will be reduced to a minimum and in this way its accuracy will be increased. In addition, the advantages of the first two means of using satellite systems will be almost completely retained.

The achievement of the accuracy of determining the mutual position of the stations of 0.1-0.3 dm, as was noted above, is connected with the translocation method. Here it is possible to organize the observations in the following way.

In the center of the area, the size of which is selected as a function of the altitude of the satellite, observations of the satellites are continuously made by the lead station (these stations can be the reference stations if there are a sufficient number of them). The moving stations in the given area operate by their usual programs. For exact determination of the differences of the coordinates of the stations, certain sections of their orbits observed from the lead and moving stations are processed jointly.

The experience in the geodetic use of satellites both in our country and abroad indicates that the planned goals are entirely admissible. Obviously they will be realized in stages. This requires the solution of complex scientific and technical problems in each phase.

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GEOPHYSICS, ASTRONOMY AND SPACE

REVIEW OF THE 'SALYUT 6' MISSION CONSIDERED

Paris AIR & COSMOS in French 5 May 79 pp 54-55

[Article by Albert Ducrocq]

[Text] The consequences of the Soyuz 33 failure have, of course, been first of all psychological. This was the first time something has gone wrong during the development of the Intercosmos Program, which employs proven techniques, and the Soviets feel that it is particularly unfortunate that this setback should have occurred when the second round of piloted lights was being launched with non-Soviet astronauts.

There can be no doubt that these flights will be delayed. But this is no inconvenience. Very wisely, the Russians had announced that the Bulgarian, Hungarian, Cuban, Mongolian and Romanian missions would be carried out before the end of 1981. And there is no a priori reason why this deadline should not be respected. The schedule does not even call for two Intercosmos flights a year. In any event, before last month's incident we had stressed the fact that it seemed to us out of the question to expect that all the Intercosmos flights currently scheduled would be carried out with the Salyut 6.

Even more serious is the suspicion that has once again been cast on the Soyuz vehicle. Everything leads us to believe that, following a long series of disappointments, perseverance had won out and the Soviet space ship could be considered to be perfected. Now even though they may not have produced dramatic consequences, the defects recently noted only with difficulty allow us to regard the equipment as technically qualified for use. They rather appear to raise the concern that they may recur.

The failures suffered by Soyuz 15 and Soyuz 23 might have been attributed to the very nature of the missions which, at that time, probably consisted less of effecting conventional kinds of rendez-vous than of testing approach conditions for a link-up with a second mooring. At the time of the Soyuz 25 failure, one might have felt that the fault lay with the astronauts. But the fact that both of them were very quickly called on to fly again ruined that hypothesis. It is apparently the equipment that is to be blamed. And in the case of the Soyuz 33 flight, the failure was ostensibly due to a technical defect.

It happened under circumstances that could have been serious.

Station Too Far Off

Soyuz 33 was launched after nightfall from the Baikonur Astrodome where, moreover, weather conditions were extremely bad. It was at 1754 GMT (or 2154 local time).

And apparently — perhaps because, before completely going out of commission, the Soyuz engine had been running irregularly — a new approach procedure had been adopted. Actually, link-ups are ordinarily made during the 17th revolution — at a point during which the space ship is flying over the Soviet Union — when piloted flights are involved (rendez-vous with the automatic Progress or Soyuz takes place during the 33d revolution). This time, it appears that the rendez-vous occurred during the 19th revolution. It seems that five changes of orbit were made with the aid of the Soyuz' main engine which — located along the axis of the ship — develops a thrust of 417 kg. It is fueled, as we know, with storable nitrogen compounds stored in the pairs of spherical tanks in the service module.

It was shortly before 2000 of the 11 April when, at a point when the Salyut 6 and Soyuz 33 were still separated from one another by some 3 km, the failure that put the main engine out of commission occurred.

At that time, the automatic approach had not been completed. The astronauts only took over control of their vehicle at a distance of 100 m from the station to perform a link-up with the aid of small engines producing a maximum thrust of 18 kg.

What could the crew do?

All the experts are in unanimous agreement. At a distance of 3 km, a visible link-up was unthinkable. Human reflexes are incapable of coming into play for reasons we have in the past had occasion to at length explain and which are still valid; namely, if you accelerate, you transfer yourself to a higher orbit which it takes longer to complete, so that you move away from the target instead of approaching it. Nor is the decision to slow down the right one, since its direct consequence is to make you lose altitude with the subsequent risk of flying below the target. The help of computers is practically indispensable.

No doubt Rukavishnikov and Ivanov could have made the necessary calculations with the equipment on board and then have controlled the ship with the auxiliary propulsion system consisting of the main engine and two engines developing a thrust of some 411 kg.

But this would have meant running a double risk. With the delay caused by a breakdown during the approach, this would in fact have meant exposing the ship to excessive fuel consumption. And in addition, it would have meant depriving themselves of any emergency procedure to resort to on the return trip in the event the back-up system itself should become defective.

In the Middle of the Night

Could not the Salyut have been maneuvered — if only by having the Soyuz 32, attached to its front end, serve as a tractor — to rejoin the Soyuz 33? The answer is probably no.

The Soyuz engine in fact provides the Salyut-Soyuz complex with a rate of acceleration of only 16 cm a second, hardly suitable for effecting an approach which requires an impulsion rate involving the production of a relatively powerful thrust during a very short period of time.

And even if the operation had by chance been possible — that is, if the velocity components of the two engines were capable of this — it could not have been but an extremely risky matter. As of the moment, the astronauts have not yet received any "driving lessons" with a Salyut. It can be piloted like a vehicle and it certainly will be in future when it will be a matter of assembling a modular station. But this has not yet been done.

And add to all this the Soyuz' limited range in terms of energy when used as a liaison vehicle — we know that it has no solar panels — and we can see that the Soyuz 33 astronauts had no other choice but to return under auxiliary engine power.

Be that as it may, as a safety measure they decided to run the engine only once. Ordinarily, reentries are made in two stages, in the sense that the Soyuz begins to shift from a Salyut orbit to a lower orbit from which point there may be an entry into the atmosphere that subjects the astronauts to a slower deceleration. For the Soyuz 33 reentry, the Hohmann semi-elliptical ballistic reentry formula was used, in which getting out of orbit is conducted at a time when South America is being flown over, communication with the USSR being at that time assured via the control ship Borovishi. At that point, the Soyuz' altitude is close to 350 km (in the late afternoon of the 12 April, the American NORAD [expansion unknown] network spotted Soyuz 33 in an orbit of 298/346 km). The auxiliary engine is operated for 213 seconds to produce a negative impulsion of 132 m a second.

This direct ballistic reentry imposes a deceleration of as much as 8 g's on the crew and subjects the Soyuz to a rugged ordeal. The cabin vibrates a great deal and the astronauts are beset with a deafening din. But the maneuver was precise. The landing took place 350 km southeast of Djezkazgan in the middle of the night at 1835 GMT or 2235 local time. The reentry conditions were such that, to crown the misfortune, instead of landing on its base the Soyuz cabin fell over on its side and rolled over the ground before coming to a stop.

However, its blinker permitted rescue helicopters to spot it very quickly. When he heard that the astronauts were safe and sound — they will be honored for their intelligence and calm behavior — flight director Victor Blagov simply said: "This is the most complicated flight we have ever attempted..."

What is most unfortunate is no doubt the fact that Rukavishnikov and Ivanov returned without even being able to provide the engineers with the information that could have shed light on the reasons why the main engine failed. It goes without saying that it in fact burned up in the atmosphere with the entire service module, whose cabin became separated from it after it was set on its reentry trajectory by the auxiliary engine.

The fact that the Russians find it impossible to carry out a rendez-vous with certainty will not fail to provide food for thought. Around the earth, an unsuccessful link-up is not catastrophic; it is merely an aborted mission. It would be quite a different matter in orbit about the moon. And this affords us an opportunity to remember that 10 years ago a moon-orbit rendezvous constituted the key operation of the Apollo Program. The Americans at that time felt that "on this point" they had achieved a 100-percent safe operation. This experience has taught us that they were not mistaken.

The Soviet astronaut situation is all the more incomprehensible since the Russians have succeeded in perfecting the most difficult operation there is, namely, automatic link-up and coupling. To date, the Progress has no record of failure...

Lyakhov and Ryumin's Food Supply

We spoke of the Progress. This brings us to Lyakhov and Ryumin, the third maintenance crew for Salyut 6, who have been somewhat forgotten in this discussion.

Now the Russians for the first time found that they were forced to revise a program, the plan for making use of Salyut 6, while their astronauts were still in space.

At first glance, one might think that the occupants of the space station were hardly concerned with the failure of Soyuz 33. It deprived them of a visit. Now when friends who are supposed to come and spend a week with you call it off at the last moment, it is certainly often a disappointment but, materially, it means less work for you and the opportunity to keep all the goodies you have prepared for them for yourself. Is not this all to the advantage of the host?

But actually, the situation cannot be described in quite these terms.

At the present stage of development of space science, deliveries from earth are in fact desirable for astronauts living in a space station for long periods of time. Soyuz and Progress supply them with food.

Progress and Soyuz

Following the failure of Soyuz 33, there are three possible hypotheses. The Soviets can send a Soyuz 34. They can send nothing at all...

At first glance, if the mission is to be prolonged, it would be desirable to send a Progress as quickly as possible.

During their 96-day flight, the astronauts of the first maintenance crew (Romanenko and Grechko) received only one Progress (Progress 1). It arrived on the 41st day of their flight, or quite noticeably in the middle of their mission.

During their 139-day flight, the astronauts of the second maintenance crew (Kovalenok and Ivanchenkov) received three Progresses. These reached them at the following times:

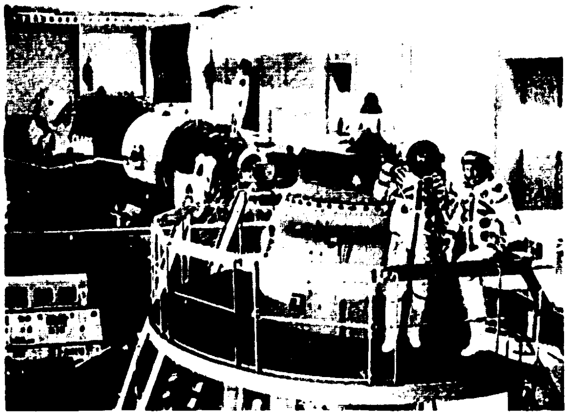
Progress 2 on the 55th day.
Progress 3 on the 86th day.
Progress 4 on the 114th day.

Now Lyakhov and Ryumin received Progress 5 on the 17th day of their flight, that is, very early, but for a specific reason, namely, the need for rapidly raising the orbit of Salyut 6 because the station had begun to lose altitude at an alarming rate and also the Soviets' desire to see to it that the material that was indispensable for reconditioning all systems after some 18 months in space reached the station as soon as possible.

If all had gone off as planned — in other words if, after a successful link-up, Soyuz 33 had unhitched itself from Salyut 6 on 18 April — we can imagine that a Progress 6 would have been launched toward the station shortly thereafter. The failure of Soyuz 33 in no way prevented sending this Progress 6; it would even have made it possible to send it off earlier than planned.

But the days went by. It was clear the Russians were going to let Lyakhov and Ryumin go for 40 days without receiving food. The sending of a Progress 6 was anxiously awaited.

Above we pointed out that there are three possible hypotheses. Actually, the Russians had to choose. Either they intended to leave Lyakhov and Ryumin in orbit for a rather limited period of time, in which case they may have had no need of anything at all. Or the astronauts were to repeat the feat of their predecessors — which would have ended in a reentry in mid-July — in which case it seems they would have needed both a Progress and another Soyuz (Soviet space ships, it appears, are only guaranteed for a stay of 3 months in space). And that being the case, in what order would the space ships have been launched?



The "international" crew of the Soviet space ship Soyuz 33 — Soviet astronaut, Nikolai Rukavishnikov, (right) and the first Bulgarian astronaut, Georgi Ivanov, (left) — in training at the City of the Stars near Moscow. In the background, the model of the Salyut used to train the crews.

11,466
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[Following is a listing of the Soviet entries from SIGNAL'NAYA INFORMATSIYA. KOMPOZITSIONNYYE MATERIALY (Signal Information. Composite Materials), a bibliographic publication of VINITI. This listing is from Volume 4, No. 5, 1979]

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1. Estimate of Interaction and Compatability of Components in Fiber Composite Material. Portnoy K. I., Zabolotskiy A A., and Turchenkov V. A. "Poroshk metallurgiya," 1978, No. 10, 64-70.

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10. Theoretical Problems of the Resistance of Structural Materials to the Effects of Various Operating Factors. Mechanical Durability of Polymer Composites. Rakhnmov R. Z. "Rabotosposobnost' stroit. materialov v usloviyakh vozdeystviya razl. ekspluat. faktorov. Kazan'," 1978, No. 1, 5-8.

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12. Production and Metallophysical Properties of a Bimetallic Strip of Steel and Lead-Tin Bronze for Bearings. Giyasbeyln Kh., Petkova N., Georgiev V. Poluchavane i fiziko-mekhanichni svoystva na bimetalni lenti ot stomana i olovno-kalayen bronz za lageri. "Mashinostroyene," 1978, 27, No. 7, 352-355. (Bulgarian)

13. Influence of Thermal Cycling on the Mechanical Properties of Natural Composites. Pirogov Ye. N., Konoplenko V. P., Svetlov I. L., Nazarova M. P., Khusnetdinov F. M., Zarubin V. A. "Fiz. i mekh. deformatsii i razrusheniya (Moscow)," 1978, No. 5, 75-85.

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22. Theoretical Problems of the Resistance of Structural Materials to the Effects of Various Operational Factors. Mechanical Durability of Polymer Composition. Rakhimov R. Z. "Rabotosposobnost' stroit. materialov v usloviyakh vozdeystviya razl. ekspluat. faktorov. Kazan'," 1978, No. 1, 5-8.

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CSO: 1870

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UDC 528.71

AEROSPACE STUDIES OF THE EARTH--COMPUTER PROCESSING OF VIDEO INFORMATION

Moscow AEROKOSMICHESKIYE ISSLEDOVANIYA ZEMLI: OBRABOTKA VIDEOINFORMATSII NA EVM (Earth Studies from Aerospace: Computer Processing of Videoinformation) in Russian 1978 signed to press 5 Oct 78 pp 2, 3-4, 239-240

[Annotation, foreword and table of contents from book edited by S. L. Orlik, Nauka, 1,450 copies, 248 pages]

[Text] This collection is devoted to the methods and algorithms used in computer processing of videoinformation about the earth's surface to study the environment and natural resources. A discussion is presented of the procedure for coordinating gridding and geometric conversions of the images obtained by optoelectronic aircraft and satellite scanning and recording systems. A study is made of the classification of multispectral measurements, methods of reducing size and compression videodata. A survey of foreign papers is presented.

The collection is designed for specialists in aerospace studies of the earth.

Foreword

The collection of articles brought to the attention of the reader contains papers on the processing and interpretation of data obtained by aerospace means after the first all-union school on studies of the earth from space.

It is now possible to consider that it is generally recognized that it is necessary to use all-purpose and specialized digital computers for processing and interpreting data gathered from studying the natural resources of the earth. Although the actual basis for the practical output from investigation of the natural resources of the earth is at the present time visual analysis of images it is clear that only combined with quantitative analysis of the data is it in a position to ensure an objective base for recommendations and conclusions.

The problems of processing the data from studying the natural resources of the earth can be broken down into two basic areas:

1. Processing of the data having the goal of establishing indeterminacy and distortions introduced by the measuring channel (radiometric and geometric corrections, consideration of the atmospheric effects, and so on.

2. The classification and interpretation analyses of the data. The articles in the collection represent both of these "technological" links of data processing completely.

The mathematical basis for the formal classification of the images is made up of traditional methods of disperse, multifactor, cluster analysis. The development of these methods is needed to analyze the natural "resolving" capacity of aerospace videoinformation, that is, to discover to what degree the statistical factors of the background origin mask the individual natural and anthropogenic images.

However, in addition to the aerospace information, the a priori information has great significance in the form of a "bank" of spectral brightness coefficients obtained during ground observations. The consideration of this information in the pattern recognition problem represents an important data processing problem when investigating the natural resources of the earth.

Another characteristic feature of the formal classification of the patterns is ignoring the textural features, the analysis of which by means of various two-dimensional transformations can provide information that is significant for classification. Both of these areas still await development. One of the important problems when interpreting the data from investigating the natural resources of the earth is the breakdown of the objects into additive components (for example, soil plus vegetation). In the collection an approach is proposed for the solution of the problem based on harmonic analysis of the brightness distribution function of elements of the earth's surface. It is possible to expect that the problems of this type lead to the necessity for using the methods and algorithms for solving improperly stated problems in mathematical physics.

The consideration of the effect of the atmosphere is a difficult scientific and technical problem connected primarily with obtaining information of the optical parameters of the atmosphere. The results presented in the collection from solving the problem of the radiation transport by the method of spherical harmonics will permit estimation of the brightness of the atmosphere as a background factor of the recording. Some general ideas are stated with respect to the principles of the combination of measuring and calculating procedures for operative correction of the influence of the atmosphere.

On the whole there is no doubt that the given collection will be a contribution to the quickly developing field of studying the earth by aerospace means, and it will arouse the interest of the specialists.

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