JPRS L/10474

21 April 1982

USSR Report

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

(FOUO 6/82)

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USSR REPORT

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

(FOUO 6/82)

CONTENTS

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FOR OFFICIAL USE ONLY

OPTICAL PROCESSING

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HARDWARE

NEW COLLECTION OF ARTICLES ON MICROPROCESSORS

Riga TSIFROVYYE USTROYSTVA I MIKROPROTSESSORY in Russian No 4, 1980 (signed to press 27 Oct 80) pp 3, 173-180

[Foreword and abstracts of articles from book "Digital Units and Microprocessors", edited by A. K. Baums, N. Ye. Zaznova and A. A. Chipa, Latvian SSR Academy of Sciences, Izdatel'stvo "Zinatne", 500 copies, 180 pages]

[Text] From the Editorial Board

This collection of articles includes works on the use and design of microprocessor systems and their individual units. The material published is divided into three sections:

1. microprocessor systems;

2. the digital units of microprocessors and automation systems;

3. programming and modeling microprocessor systems.

The first section reviews the questions of construction of microprocessor systems and various ways of interlinking them with real objects, especially in subsystems to control electric trains and motor vehicles.

The second section includes articles which treat the questions of construction of the particular assemblies of microprocessor units and other discrete automation systems. Special attention is devoted to questions of organizing links among the individual assemblies.

The first section is devoted to questions of development of software for microprocessor systems using cross program equipment, in particular cross compilation of programs and modeling work. A special algorithmic language for developing programs to test digital microcircuits is proposed.

The material in this collection can be used in the development of digital units for various purposes. We ask that all requests and remarks be sent to the following address: 226006, Riga, Ulitsa Akademiyas, 14, Institute of Electronics and Computer Technology of the Latvian SSR Academy of Sciences.

Abstracts

UDC 681.325.5-181.4:62-83

A. K. Baums, V. T. Yermolov, A. A. Chipa, et al., "Use of a Series K580 Microprocessor To Control the Thyristor Pulsed Current Regulator of the Traction Engines of an Electric Train."

This article considers the use of a microcomputer as a unit to control the traction drive of an electric train, employing a thyristor pulsed regulator. The authors present the structure of a controller developed on the basis of a K580IK80 microprocessor, a flowchart of the control algorithm, and time diagrams of control pulses during combined testing of the power equipment and microcomputer. The article has seven illustrations and two bibliographic entries.

UDC 681.32-181.48:629.113

Yu. N. Andriyevichev, V. D. Komarov, N. V. Kochetov, et al., "Microprocessor System for Controlling the Moment of Ignition."

This article describes a system to control the moment of ignition of the fuel mixture for internal combustion engines. The system was built using a microcomputer based on a K580IK80 microprocessor. The authors show how the ignition advance angle depends on input parameters, present a structural diagram of the system and a flowchart of the program for finding the ignition advance angle, and describe the system interface. The use of this system in a motor vehicle makes it possible to reduce fuel expenditure up to 15 percent and lower the toxicity of exhaust gases. The article has three illustrations and one bibliographic entry.

UDC 681.32-181.48:629.113

Yu. N. Andriyevichev, V. D. Komarov, and N. V. Kochetov, "The Effect of the Parameters of an Anti-Interlock Braking System Control Block Based on a Microcomputer on the Controllability, Stability of Trajectory, and Braking Efficiency of a Motor Vehicle."

This article presents an analysis of the influence of the parameters of a block to control an anti-interlock system built using a microcomputer based on the K580IK80 microprocessor on the controllability, stability of trajectory, and braking efficiency of a motor vehicle. The authors review the fundamental laws of control on which the functioning of contemporary anti-interlock systems is based and possible ways to apply them in motor vehicles. They give a flowchart of a microcomputer and its software. The analysis demonstrates the possibility of realizing a block to control an anti-interlock system on a microcomputer and to insure high precision of execution of the law of control of an anti-interlock system for a motor vehicle.

UDC (681(3T-181)46:629:113

Yu. N. Andriyevichev, Yu. N. Ivanov, V. D. Komarov, et al., "Resident System for Designing and Debugging a Microcomputer That Realizes the Laws of Control for Engine Assemblies and an Anti-Interlock Braking System."

This article describes a resident system for debugging motor vehicle microprocessor automatic control systems realized on the basis of the K580IK80 microprocessor. The hardware and software of the system are considered. The authors give a structural diagram of a resident design system. All the software was developed on the modular principle, which makes it possible to build up and refine the system further. The system described makes it possible to design and debug all presently known motor vehicle automatic control systems. The article has one illustration and two bibliographic entries.

UDC 681.327-181.4

Ye. A. Kalin'sh, "The Development of Interface LSIC's of Microprocessor Systems."

This article reviews the question of development of interface LSIC's [large-scale integrated circuits] of microcomputers. The authors present a variation of the application of universal interface LSIC's (third generation) and a comparison of the use of first and second generation of LSIC's with the example of parallel data copying. The article has five illustrations and eight bibliographic entries.

UDC 681.327.2

G. V. Tabuns, "Hardware Simulator of Control Memory."

This article reviews the questions of building optimal hardware for adjusting digital units that contain microprogram memory. The author gives an analysis of the basic parameters and requirements for the function of hardware simulators. The analysis may be used as a recommendation for building such units. The article has one illustration and eight bibliographic entries.

UDC 681.325.53:621.391.23.037.372

D. K. Zibin', "Duplex Interlinks Among Assemblies of a Digital Computer."

This article reviews structural diagrams of the interlinking lines of transmitting and receiving units that use multivalued signals. The author proposes duplex interlink lines, that is, two independent channels that work in opposite directions on one interlink line. Changing to four-valued signals cuts the number of interlinked lines in half compared to two-valued signals, while combining two channels into one produces an additional benefit. The article has two illustrations and four bibliographic entries.

UDC 681.3.04

D. K. Zibin', "Physical Coding of Multivalued Signals."

The articles considers one-, two-, and three-dimensional coding of variables of multivalued algebraic logic by physical signals that "carry" the values of the variables and gives appropriate geometric interpretations. The author reviews the drawbacks of one-dimensional coding and ways to eliminate them. Different coding variations use positive, negative, shifted, symmetrical, paraphasal, and other logics, for which appropriate definitions are given. The article has four illustrations and five bibliographic entries.

UDC 681.325

V. Ya. Zogurskiy, "Systems for Analog-Digital Conversion of Signals with Periodic Discretization."

This article reviews the primary types of discretization operations during analog-digital conversion of signals. On the basis of a generalized description of analog-digital conversion the author proposes an algorithm for high-speed analog-digital conversion by combining the operations of discretization and quantization. The algorithm accomplishes periodic discretization of the input signal. The article gives the structures of system variations of analog-digital convertors with different types of quantization, by amplitude and time. There are five illustrations and five bibliographic entries.

UDC 621.374.2(088.8)

V. Ya. Zogurskiy and M. A. Arnit, "Device for Precise Systemization of Signals."

This article reviews the principal variations of synchronization units with possible precision of alignment to synchronizing signals to a level of 0.5-1 nanoseconds. The authors analyze different forms of constituent parts in the units and possibilities of stabilizing the parameters of synchronizing signals. They show the possibilities of using the devices. The article has three illustrations and four bibliographic entries.

UDC 621.373

V. A. Bespal'ko, "High-Frequency Frequency Multiplier for Problems of Precise Measurement of an LDIS Signal."

This article reviews a variation of realizing a high-frequency frequency multiplier with an output frequency of 400 megahertz, oriented for use in the analog-digital convertor of a discrete laser doppler velocity measurement [LDIS] system. The high reliability and small dimensions of the multiplier are achieved by constructing the principal assemblies on the basis of logical integrated circuits. This article has two illustrations and six bibliographic entries.

UDC 681.3.06

P. A. Tiss, "The Process of Cross Compilation of Programs on YeS Computers for Microcomputers Based on the K580 Microprocessor Series."

This article reviews the process of cross compilation from macroassembler language and a high-level language by systems of programs on a YeS computer for microcomputers based on the K580 microprocessor series. The author presents the principle of using a library of initial modules and formulating the initial text of the program. The article has three illustrations and four bibliographic entries.

UDC 681.324:681.3.06

Ye. Ye. Ekmanis, "Construction of a Model of a Program for Modeling Its Parallel Execution."

This article considers the theoretical premises of construction of a model of a program to model its parallel execution in a computing system consisting of a central processor, a central memory unit, and a changing number of working processors. The article does not consider construction of a model of system hardware. The article has one illustration and four bibliographic entries.

UDC 681.32-181.48.001.57

N. Ye. Zaznova, "Package of Programs for Modeling a Microprocessor Set of K589 Large-Scale Integrated Circuits."

This article describes a package of programs designed for modeling microprocessor systems constructed on the basis of a set of series K589 LSIC's. The package is written in FORTRAN IV and contains subroutines for modeling specific microcircuits of the set, microassembler subroutines, and subroutines for computing logical operations using whole number arithmetic. The article has one illustration and two bibliographic entries.

UDC 621.3.049.77.001.57:681.3

S. B. Bondar', "Nine-Character Modeling of Logical Circuits."

The reliability of results of studying logical circuits by the simulation modeling method depends significantly on the way that the process of distribution of information in the circuit is represented. The purpose of this article is to describe a nine-character modeling alphabet that correctly represents the information characteristic of real signals in a logical circuit. The author reviews combination and sequential circuits that realize elementary logical conversions in the given set of characters. The article has five tables, one illustration, and two bibliographic entries.

UDC 683.32.06-181.48

V. M. Kosik, V. V, Kremskoy, A. V. Olekhnovich, and A. I. Yatsunov, "The TALL-1 Problem-Oriented Algorithmic Language for Programming the Testing of Digital Microcircuits."

This article describes the TALL-1 programming language, which is designed for use as the input language of general-purpose information-measurement computing systems that make it possible to test any type of LSIC. The article has one illustration and five bibliographic entries.

11,176
CSO: 1863/44

UDC 681.325.5-181.4:62-83

USE OF SERIES K580 MICROPROCESSOR TO CONTROL THYRISTOR PULSED CURRENT REGULATOR OF ELECTRIC TRAIN TRACTION ENGINES

Riga TSIFROVYYE USTROYSTVA I MIKROPROTSESSORY in Russian No 4, 1980 (signed to press 27 Oct 80) pp 4-16

[Article by A. K. Baums, V. T. Yermolov, A. A. Chipa, G. E. Vasarin'sh, R. M. Berzin and L. Yu. Veytsman]

[Excerpts] One of the areas in which microprocessors are beginning to be used successfully is electric transportation.

This article considers the use of series K-580 microprocessor to control the thyristor pulsed armature current regulator of the traction engines of an electric train.

Flowchart of the Control System of the Traction Drive of an Electric Train

Figure 5 below shows a flowchart of a control system for the traction drive of an electric train using a microcomputer. In it the microcomputer plays the role of controlling automaton. The input signals are: a signal from the generator (400 hertz) that assigns the frequency of regulation; signals from the analog-digital convertor which represent in number form the current value of the armature current of the traction engine; signals from the engineer's console, which give the magnitude of the set current; signals from the position counter of the rheostat force controller, representing the four-bit code of the position of the controller; and, signals from the tachometer characterizing the current speed of the train.

In conformity with the working program, the microcomputer stored in a read-only (permanent) memory issues of the following control signals: pulses of a certain length to block and unblock the TIR (thyrister pulsed regulator); the logical level for the transfer circuit of the power controller; a pulse to launch the analog-digital convertor and a strobe to select the channel of the convertor; logical levels for the program mechanism to indicate the settings being given.

The microcomputer. A model of a single-board microcontroller based on the K-580IK80 microprocessor was used as the control machine to perform the

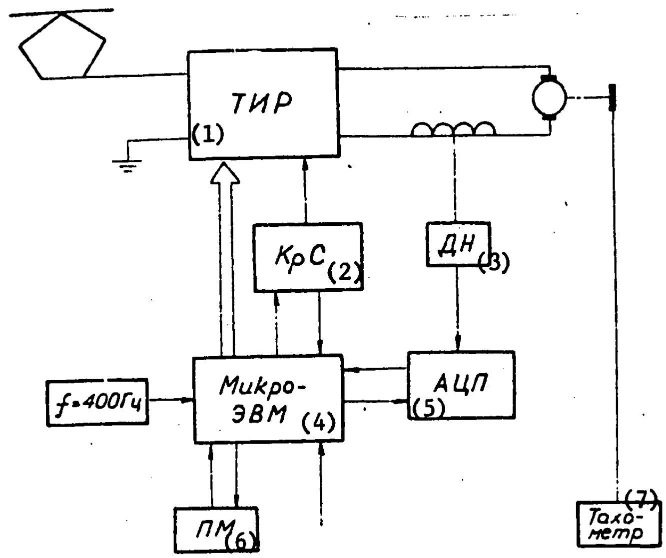

Figure 5. Flowchart of the Traction Drive Control System of the ER-200 Electric Train.

Key: (1) Thyrister Pulse Regulator;
(2) Power Controller;
(3) Voltage Sensor;
(4) Microcomputer;
(5) Analog-Digital Convertor;
(6) Program Mechanism;
(7) Tachometer.

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above-described task. The microcontroller has a comparatively simple structure and consists of the following basic components:

- generator of two sequential timing pulses with shapers, assembled on a series 155 integrated circuit, transistors, and discrete elements;

- the large-scale integrated circuits of the K580IK80 microprocessor;

- static-type internal memory with a capacity of 256 bytes (eight K505RU4 chips);

- reprogrammable read-only memory with ultraviolet data erasure and a capacity of 1,000 bytes (four K505RRI chips);

- a system controller assembled on a K589IR12 chip, a K589AP16 chip, and a series 155 integrated circuit;

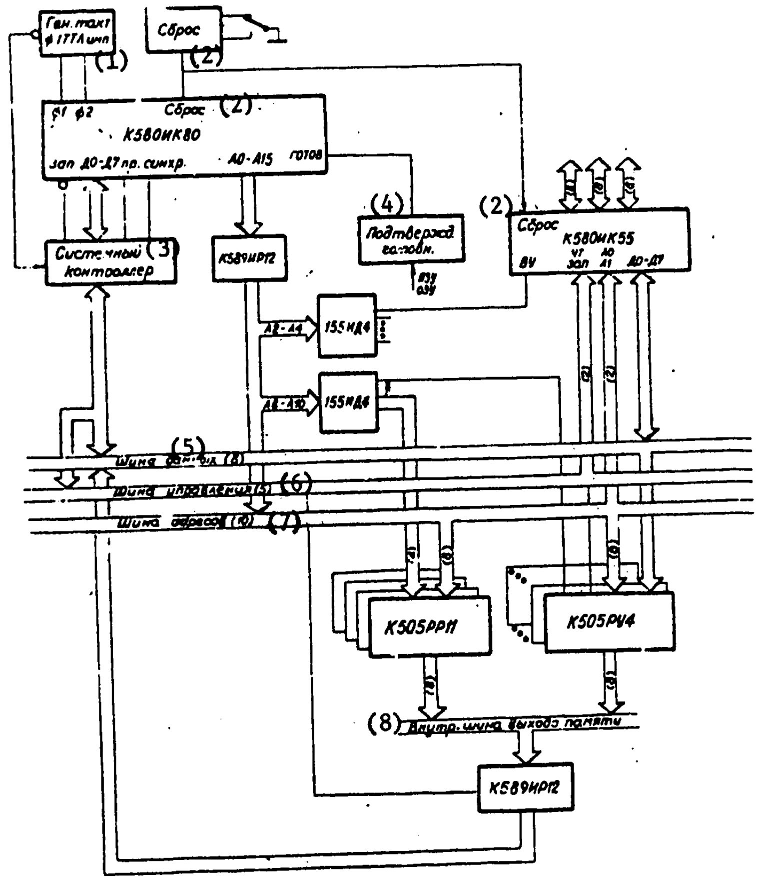

Figure 6. Block Diagram of a Controller Based on the K580IK80 Microprocessor

Key:
(1) Timer;
(2) Clear;
(3) System Controller;
(4) Confirmation of Readiness;
(5) Data Line;
(6) Control Line;
(7) Address Line;
(8) Internal Line for Memory Output.

- an address line amplifier (K589IR12 chips);
- decoder for selection of pages in memory (internal and reprogrammable read-only) and peripherals (155 ID4 integrated circuits);
- K580IK55 parallel interface.

Input signals are fed to the microcontroller and control signals are outputted to the K580IK55 parallel interspace. The output signals have TTL levels.

Table 1 [not reproduced] shows the distribution of input/output signals by ports A, B, and C of the interface.

The analog-digital convertor. A standard ATsPN-1 convertor from the Elektronika-IOOI set was used to convert the current value of the code of the traction engine to a digital parallel code in the system described.

Conversion time for the ATsPN-1 is 20 microseconds and the word length is 10 bits (without a sign bit). Eight high-order digits of the ATsPN-1 were used. The analog quantity being converted, in the form of a voltage read from the voltage sensor proportional to the current of the traction engine, was fed to one of the 16 channels of the ATsPN-1. The procedures for switching the channel selected and starting the ATsPN-1 were carried out on instructions from the microcontroller.

Regulation frequency generator. The frequency of regulation of the current of the traction engine is assigned by a generator (f = 400 hertz) which is assembled on a series 155 integrated circuit and discrete components. The output signal of the generator has a TTD level and a "meander" form. The length of the period T is 2.5 milliseconds.

The traction engine control system using a microcomputer was tested on a laboratory stand in a rheostat brake regime. An IDT-004 engine with an output of 210 kilowatts was used as the traction machine, and the thyrister pulse regulator of an EL-200 electric train was used as the regulator (box RYaA.030).

The results of the testing demonstrated the advantages of using microprocessors in assemblies to control the power equipment of an electric train. These advantages found expression in improved qualitative characteristics of control, greater flexibility and compactness of the control system, and an improvement in the reliability indicators of the electric drive.

11,176
CSO: 1863/44

UDC 621.373

HIGH-FREQUENCY FREQUENCY MULTIPLIER FOR PROBLEMS OF PRECISE MEASUREMENT OF LDIS SIGNAL

Riga TSIFROVYYE USTROYSTVA I MIKROPROTSESSORY in Russian No 4, 1980 (signed to press 27 Oct 80) pp 106-115

[Article by V. A. Bespal'ko]

[Text] As we know [1], measuring the signal of the LDIS (laser doppler measure of velocity) of gas flows amounts to measuring the frequency ω of a radio pulse with the gaussian envelope

$$u(t) = A\,\exp\left(-\frac{t^2}{2a^2}\right)\cos\omega t, \qquad (1)$$

whose appearance at the output of the photo receiver is caused by a particle moving with the flow intersecting the interference bands formed by the laser beam. Measuring the frequency of the doppler signal is a fairly complex technical problem involving the random character of the moment of appearance of the radio pulse, its brief duration (tenths of a microsecond), and the presence of noise. The problem is solved using sets of measurement, computing, and auxiliary equipment — LDIS measurement systems.

In the case of the single-particle LDIS regime the discrete method of measuring the frequency ω by the number of times the signal intersects the zero level is best [1]. In this case the frequency is defined as

$$\omega = \pi\frac{N}{T}, \qquad (2)$$

where T is the relation of the radio pulse, and N is the number of times the signal intersects the zero level.

The basic unit that determines the precision of the measurement components of a discrete LDIS system is the analog-digital convertor of time interval T [2]. The comprehensive approach to solving the problem of precise analog-digital conversion of brief time intervals necessitates not only high-speed conversion equipment (selector counters and the like), but also appropriate sources of a standard frequency. Thus, to measure the quantity T with a precision of approximately 0.1 percent (the precision of the LDIS method itself, defined by noise) by the direct calculation method, it is necessary to have a frequency in the range 0.1-1.0 gigahertz for the standard quantizing generator. The fact that this generator must be an integrated part of a single measurement system determines the principal requirements for it: small dimensions; uniformity of basic elements used in the generator and measurement system; coordination of the parameters of the output signal (frequency, levels, and loading capacity) with other elements of the analog-digital convertor, and so on. In many respects the well-known high-frequency frequency standards do not meet these requirements.

In what follows we will consider a variation for realizing a high-frequency multiplier with an output frequency of 400 megahertz, oriented for use in the analog-digital convertor of a discrete LDIS system.

In addition to traditional methods of singling out and amplifying the harmonics of the signal being multiplied, the problems of multiplying a frequency are often solved today by using pulsed systems of phased automatic frequency tuning (IFAPCh) with division of the frequency in a feedback system. These systems permit large multiplication factors. Because rigorous requirements are not imposed for the form of the standard signal in measuring units for time intervals, practically all the assemblies of an IFAPCh system can be constructed on the basis of logical integrated circuits, thus achieving high reliability, small dimensions, and simplicity of layout. The maximum speed of contemporary ECL (emitter coupled logic) integrated circuits is about 200 megahertz (series 100 and 500), and in the multiplier under consideration the input signal (5 megahertz) is first multiplied to 200 megahertz using an IFAPCh system, and then to 400 megahertz by singling out and amplifying the second harmonic (see Figure 1 below).

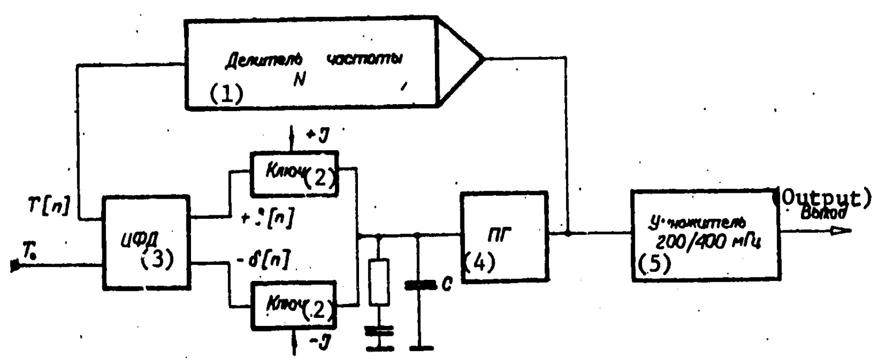

Figure 1. Block Diagram of Frequency Multiplier.

Key:
(1) Frequency Divider;
(2) Key;
(3) Pulsed Frequency Detectors;
(4) Generator Being Adjusted;
(5) Multiplier 200/400 Megahertz.

The most significant factor that affects the quality of a frequency multiplier with an IFAPCh system is modulation of the output signal by the frequency of the multiplied signal. "Complex" pulsed phased detectors of the "access-storage" type are usually used to eliminate this problem [3]. It is preferable in this case to switch to an IFAPCh system supplemented by integrating the output of the pulsed phase detectors. One such variation is the astatic IFAPCh (see Figure 1 above) with an integrator on keys and a broad-pulse phase detector with a unit to determine the sign of a phase mismatch [4]. Signals from the outputs of the pulsed phase detectors that carry information about either the sign or the magnitude of the deviation of the phase shift of the input signals from a certain constant value are converted by key elements into equipalar pulses of current and integrated in space C. The voltage from space C influences the frequency of the generator being adjusted (trimmed).

In a set regime the working algorithm of the pulsed frequency detectors may be described approximately by the difference equation

$$\delta(n) = T_0 - T[n], \qquad (3)$$

where $\delta(n)$ is the time mismatch identified by the detector; T_0 is the period of the signal being multiplied; $T[n]$ is the period of the signal at the output of the divider in regulation cycle n. If we introduce the system amplification factor p :

$$p = NK_N K_M, \qquad (4)$$

where N is the coefficient of division of the divider; $K_N = J/C$ is the coefficient of conversion of the integrator; and, K_M is the steepness of control of the generator being adjusted, from expression [3], the behavior of the system can be described by a first-order linear difference equation with constant coefficients:

$$T[n+1] - (1-p)T[n] = pT_0. \qquad (5)$$

From equation [5] it is possible to determine the condition of system stability

$$0 < p < 2 \qquad (6)$$

and the nature of change

$$T[n] = T_0 - \delta[n](1-p)^n, \qquad (7)$$

where $\delta[0]$ is the initial time mismatch for inputs of the pulsed phase detectors. It follows from expression [7] that, where condition [6] is met, the time mismatch for the inputs of the pulsed phase detectors in a steady regime is equal to zero regardless of the initial conditions:

$$\delta_{уст} = \lim_{n \to \infty} (T - T[n]) = 0, \qquad (8)$$

in other words, this system is astatic with respect to the adjusting (setting) action. Because the detector is in a state where there are not signals for both outputs, the voltage in space C changes only when there is a mismatch for the inputs of the pulsed phase detectors and thus the effect of reducing modulation is analogous to the use of an "access-storage" amplitude detector with simpler hardware realization and high working precision.

It should be noted that expression [5] correctly describes the system only in a steady regime when the phase and time mismatches for the inputs of the pulsed phase detectors can be equated. To consider transfer processes in the system requires a precise description of it in higher-order equations, but the length and nature of the transfer process is not significant in the multiplier. Analysis of the factors that affect the level of phase fluctuations of the output signal shows that to reduce them it is necessary to increase the comparison frequency and amplification factor in the system as much as possible and also reduce time fluctuations in elements of the circuit.

The principal assemblies of the multiplier (see Figure 2 below) are: the phase detector, integrator, high-frequency adjustable generator, frequency divider on emitter coupled logic triggers, and 200/400 megahertz multiplier.

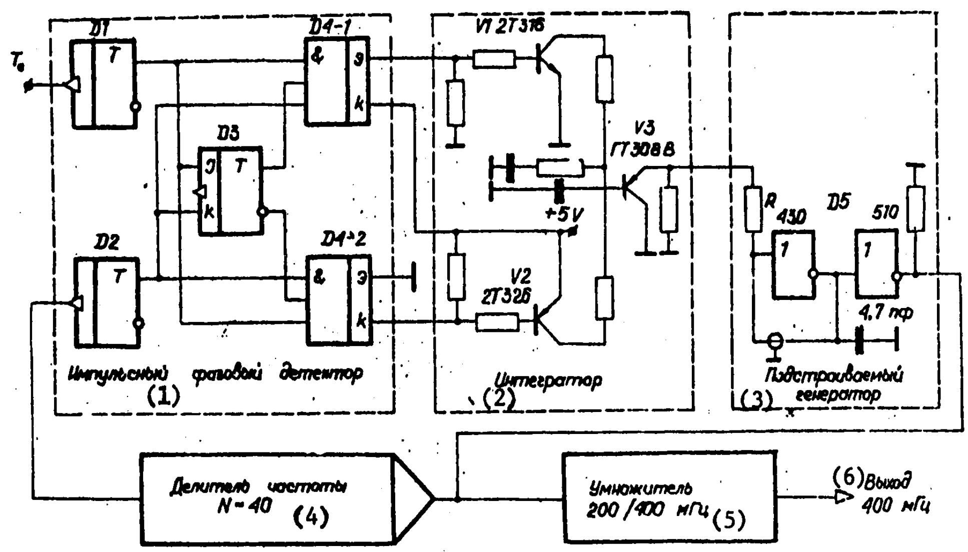

Figure 2. Diagram of the Principal Assemblies of the Multiplier: ДI-Д3 — K130 TBI; Д4 — K1LN301; Д5 — K100 LMOI.

Key: (1) Pulsed Phase Detector;
(2) Integrator;
(3) Generator Being Adjusted;
(4) Frequency Divider;
(5) 200/400 Megahertz Multiplier;
(6) Output, 400 Megahertz.

The phase detector is assembled on elements ДI-Д4. As already pointed out, the working algorithm of the detector was such that in addition to determining the absolute magnitude of the phase (or time) mismatch $\delta[n]$, it should separate outputs by sign $\delta[n]$, that is, realize the function

$$y = \mathrm{sgn}\,\sigma[n]. \qquad (9)$$

To perform these functions the detector should contain a sign determination unit that switches the two circuits for identifying the absolute value of the mismatch [4]. As we know, the "I" circuit is the most precise circuit for identifying the phase shift of pulsed signals, and an "I-K" trigger (Д3) can be used to determine the sign. The output signal of this detector will be zero when the input triggers (Д1, Д2) are working in opposite phases. When the pulsed phase detectors are built with high-speed series 130 or 530 TTL integrated circuits a time solution on the order of several nanoseconds is insured.

The integrator consists of two controlled keys (V1, V2), storage space C, and an isolating series on transistor V3. The currents of the charge and discharge keys of the stage space are selected according to expression [4] based on the condition of system stability [6], the steepness of control of the generator being adjusted, and the division factor of the divider.

The principal requirements made of the generator being adjusted in the frequency multiplier are: insuring a generation frequency of 200 megahertz ±10 percent and low, brief instability. The simplest way to solve this problem is to use a relaxation generator on an inverting emitter coupled logic logical element and a delay line in the feedback circuit [5]. A cable of a definite length (about five centimeters) is used as a delay line, and frequency control is accomplished by changing the actual delay of the microcircuit when regulating the voltage on the loading resistor. The period of repetition of pulses of the output of the generator may vary in the range 180-220 megahertz with a change in the control voltage of about two volts. The control characteristic in this frequency range is close to linear. It should be noted that when destabilizing factors related to the autonomy of the cycle are operative, the relaxation generator has the ability to accumulate the dispersion of the period between adjustment cycles, in other words, the phases of output signals that are adequately dispersed in time of quasirandom. This makes it possible to insure the independence of tests when the multiplier is used as a standard generator in digital measures of time intervals with static averaging [6].

The frequency divider is built on series 100D-triggers, while the 200/400 megahertz multiplier uses a conventional circuit with resonance contours.

The basic technical specifications of the multiplier are: input frequency — five megahertz; multiplication factor — 80; levels of output signal — at least five volts. The shape of the output signal is close to sinusoidal, and its instability is not more than $5 \cdot 10^{-6}$ milliseconds.

It is recommended that a synchronizable 4I-40 quartz generator be used as the source of the signal being multiplied.

FOOTNOTES

1. G. I. Grozdovskiy, "Analysis of the Precision of LDIS Measurements," TR. TSAGI, 1976, Vyp 1750, pp 5-31.

2. Yu. N. Artyukh, "Convertor for Frequency-Time Measurements in LDIS Systems," in "Eksperimental'nyye Metody i Apparatura dlya Issledovaniya Turbolentnosti. Tr. II Vsesoyuz. Soveshch." [Experimental Methods and Equipment for the Study of Trubulence. Proceedings of the 2nd All-Union Conference], Novosibirsk, 1977, pp 159-160.

3. S. K. Romanov, "Analysis of FAPCh System with Memory and Delay," VOPROSY RADIOELEKTRONIKI. SER. TEKHNIKA RADIOSVYAZI, 1971, Vyp 7, pp 89-98.

4. Yu. N. Artyukh, and V. A. Bespal'ko, "Phase and Frequency-Phase Detectors for Astatic IFAPCh Systems," in "Tsiforvyye Ustroystva i Mikroprotsessory" [Digital Devices and Microprocessors], Vyp 2, Riga, "Zinatne", 1977, pp 164-171.

5. S. G. Basiladze, "Integrated Circuits with Emitter Coupling and Their Application in Nanosecond Nuclear Electronics," PRIBORY I TEKHNIKA EKSPERIMENTA, 1976, No 6, pp 7-19.

6. Yu. N. Artyukh, and V. A. Bespal'ko, "Pulse Generator," USSR Author's Certificate No 571882, OTKRYTIYA. IZOBRETENIYA. PROM. OBRAZTSY. TOVARNYYE ZNAKI, 1977, No 33.

11,176
CSO: 1863/44

UDC 681.3.06

CROSS COMPILATION OF PROGRAMS ON YeS COMPUTERS FOR MICROCOMPUTERS BASED ON K580 MICROPROCESSOR SERIES

Riga TSIFROVYYE USTROYSTVA I MIKROPROTSESSORY in Russian No 4, 1980 (signed to press 27 Oct 80) pp 116-123

[Article by P. A. Tiss]

[Text] In connection with the possibility of broad use of microprocessors and microprocessor systems in various fields of engineering and in everyday life, many different programs must be formulated. As the volume and complexity of the programs increase, it becomes harder and harder to write them in machine codes. Automation of programming on large computers and minicomputers, i.e. programming languages, is being used to ease the job. Compiler programs which occupy a significant memory volume are used to convert the text of programs written in the initial language into the machine codes of the particular computer.

In most cases the application of microprocessors is highly specialized and the working programs are copied into read-only (or reprogrammable) memory, while the internal memory has a small volume that does not permit it to be used for compiling programs. Assembler-type programming languages and high-level languages have been developed to use and accelerate the process of writing programs for microprocessors, and the compilers work on large computers and minicomputers and produce object programs in the system of instructions of the microprocessor. These compilers have received the name "cross compilers."

The present article describes the processes of compilation by systems of programs that include an ASSA-YeS cross compiler from macroassembly language and a TL/M-YeS cross compiler from the high-level PL/M language [1]. The result of this process is an object program that corresponds to the system of commands of the K580 microprocessor series [2, 3]. The processes of compilation are generally similar in the YeS [Unified System] conventional operating system and disk operating system. Therefore, the special features of the process in the YeS disk operating system are described separately.

The Cross Compilation Process in the YeS Operating System

Figure 1 below shows a structural diagram of the compilation process using the ASSA-YeS cross compiler. After loading control program 4 begins feeding punched cards 1 of control statements that define the work regime from the system input. If the compilation regime is selected from the punched card, program 2 is executed and the initial text of the program is copied from punched card 1 to disk 7.

If the work regime using the library of initial modules is selected, program 5 is loaded for execution. It feeds the names of the modules that must be included in the initial program from punched cards 1, read them from the library of initial modules 3, and formulates the sequential set of data on disk 7. During the work of programs 4 and 5 diagnostic messages are outputted to printer 6.

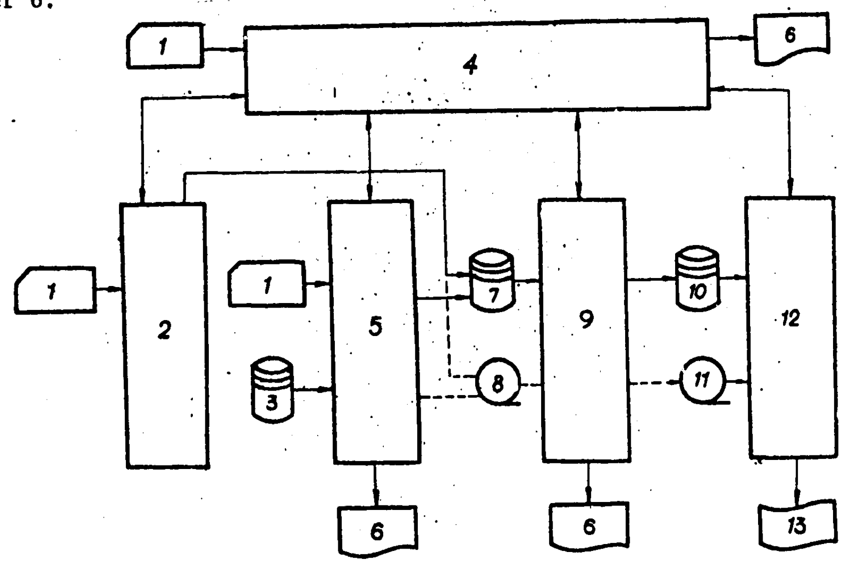

Figure 1. The Process of Cross Compilation from Macro-assembler Language.

The initial text of the program may be supplemented from punched cards and formed on magnetic tape 8, not on the disk. The next stage is loading and running the cross compiler 9, which is a double-pass unit and after the first pass prepares unit 7 or 8 for beginning to set up the data. Printer 6 outputs the initial text of the program, the object code, the table of symbols, and error messages. The sequential set of data containing the object program is formed on disk 10 or magnetic tape 11. The set of data consists of entries in a definite format.

When selecting the regime for output to punched tape, program 12 is loaded and run and unit 13 outputs punched tape in the above-described format. The process of cross compilation is accomplished by requesting a procedure which is run in one step and contains all the necessary control statements of the YeS operating system [4].

Figure 2 below gives the structural diagram of the compilation process using the PL/M-YeS cross compiler. In this case the procedure consists of two steps. Performance of the first step of the procedure begins with loading and executing control program 5. System punched card input 1 feeds statements to control the compilation regime. If the regime that uses the library of initial modules 2

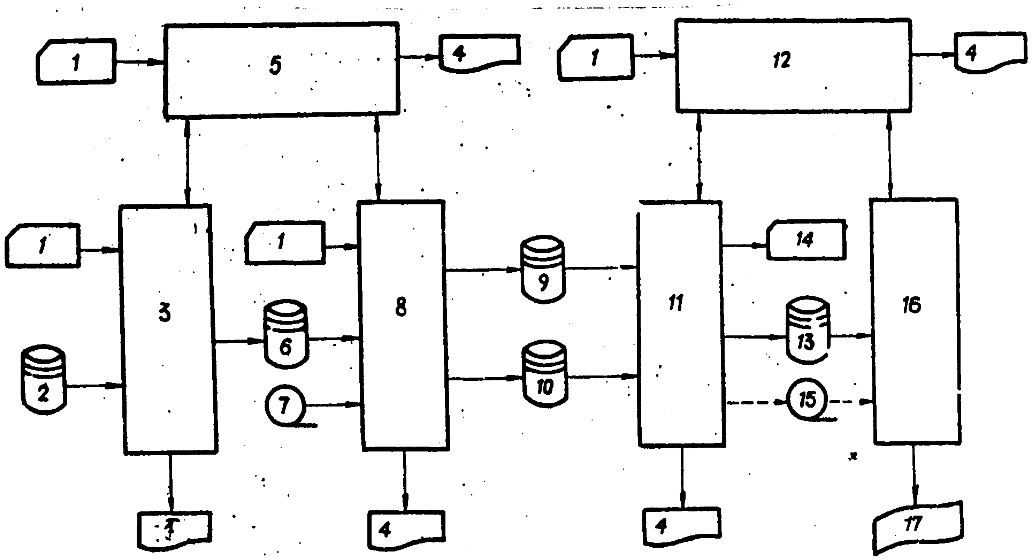

Figure 2. Process of Cross Compilation from High Level Language.

is selected, program 3 is run. Those initial modules whose names are fed from unit 1 are selected from the library. The sequential set of data consisting of the initial modules whose order was indicated when their names were fed is formed on disk 6. After this the program of the first pass of cross compiler 8 is executed; it feeds and processes the initial test of the program from unit 6. In addition, part of the initial program can be represented in unit 1 and on magnetic tape 7. System printer 4 outputs the complete text of the initial program and diagnostic messages. Sequential sets of data that contain the intermediate language and tables of symbols are formed on disks 9 and 10. If a regime is assigned that does not use the library of initial modules, program 3 is not executed.

The second step of the procedure begins with execution of control program 12, which immediately loads for execution the program of the second pass of cross compiler 11. Control statements are fed from unit 1, while the intermediate language and table of symbols are fed from units 9 and 10. The tables selected by the control statement, the text of the object program, and diagnostic messages are outputted on unit 4. If desired, the object program may be outputted to units 13 and 15 or to punched card unit 14. The format when outputting the object program is identical to the format outputted by the ASSA-YeS cross compiler. If the punched tape output regime is selected, program 16 is run and outputs the object program to unit 17.

Special Features of Using the Library of Initial Modules in the YeS Disk Operating System

The process of compilation in the YeS disk operating system differs fundamentally if a library of initial modules is used. We will now consider in detail the process of formulating the initial program for the ASSA-YeS and TL/M-YeS cross compilers (see Figure 3 below).

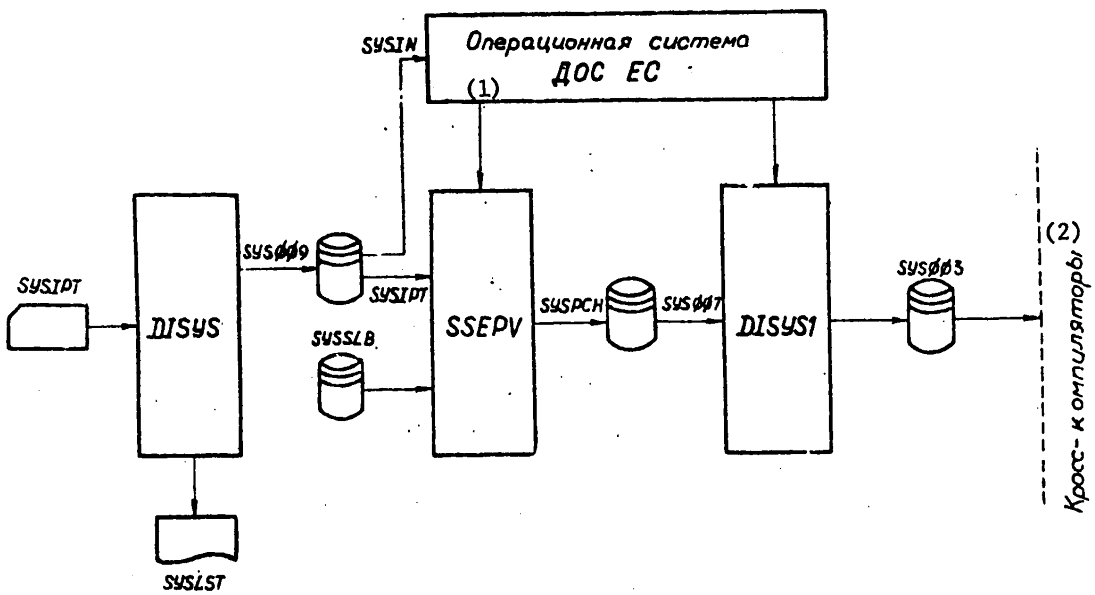

Figure 3. Process of Formulating the Initial Text of a Program from the Library in the YeS Disk Operating System.

Key: (1) YeS Disk Operating System;
(2) Cross Compilers.

The DISYS program feeds the name of the cross compiler and the names of the modules from the library which must be included in the initial program. The statements and directions of the YeS disk operating system and the input information for the SSERV program are outputted to logical unit SYS ØØ 9. Before completion of the work of the DISYS program the name SYSIN is given to logical unit SYS ØØ 9 for feeding system statements and data. The YeS disk operating system requests service program SSERV which serves the library of initial modules. The modules whose names were fed during the running of the DISYS program are selected from the library. The SSERV program outputs the modules to the logical unit of the system punch SYSPPH, which is called SYS ØØ 7 for the DISYS 1 program. The DISYS 1 program feeds the initial text from logical unit SYS ØØ 7, processes it, and outputs it to logical unit SYS ØØ 3 as a sequential set of data. The cross compilers use logical unit SYS ØØ 2 to feed the initial text of the program.

FOOTNOTES

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2. A. A. Vasenkov, "Microprocessors," ELEKTRONNAYA PROMYSHLENNOST', 1978, No 5, pp 7-9.

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CSO: 1863/44

UDC 681.32-181.48.001.57

PACKAGE OF PROGRAMS FOR MODELING MICROPROCESSOR SET OF K589 LARGE-SCALE INTEGRATED CIRCUITS

Riga TSIFROVYYE USTROYSTVA I MIKROPROTSESSORY in Russian No 4, 1980 (signed to press 27 Oct 80) pp 134-142

[Article by N. Ye. Zaznova]

[Excerpts] Modeling on general-purpose computers is an important part of the process of developing microprocessor units. It permits checking the correctness of the fundamental structural concepts and the algorithms for performance of particular operations and programs to be copied into the read-only (permanent) memory of the microprocessor system. This article considers a package of programs designed for modeling computer units built on the basis of a set of series K589 microprocessor LSIC's [large-scale integrated circuits].

Series K589 is a microprocessor set consisting of processor, storage, and interface integrated circuits built with the technology of transistor-transistor logic with Schottky diodes [1]. Its architecture is based on the "3-M" (microprogram ability, modularity, and mainline [pipeline]) principle. The two basic components of the set are the K589IKS1 microcircuits of the microprogram control block and the K589IK02 central processor element. In combination with standard read-only, programmable, and internal memory they can form highly productive processor and monitor circuits. The supplementary microcircuits of the set — the K589IK03 accelerated transfer circuit, the K589IR12 multiregime buffer register, the K589IK14 polarity interrupt block, and the K589AP16 and K589AP26 line shapers — increase the productivity and capabilities of the primary components of the set.

The package of programs for modeling includes subroutines that model the width of particular microcircuits of the sets as well as a number of auxiliary subroutines. They are written in FORTRAN IV language and were tested in use with the G-translator included in the YeS [Unified System] operating system.

Block IK58901 has 16 internal triggers, 15 of which are conventional synchronized triggers which receive information only when the synchronization signal is zero and output it to the output of the block when the synchronization signal is one. One trigger, the trigger of the sign Φ, is a D-type trigger which receives information when the systemized signal is one and does not change its state when the value of the signal is zero.

FOOTNOTES

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2. N. Ye. Zaznova, "Modeling Microprocessor Systems Using FORTRAN IV," in "Tsifrovyye Ustroystva i Mikroprotsessory" [Digital Units and Microprocessors], Vyp 3, Riga, 1979, pp 59-69.

11,176
CSO: 1863/44

UDC 681.325+681.335

ATSP-35 ADAPTIVE ANALOG-DIGITAL CONVERTER

Kiev ELEKTRONNOYE MODELIROVANIYE in Russian No 1, Jan-Feb 81 p 104

[Article by Doctor of Technical Sciences Andrey Ivanovich Kondalev, department head, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, Kiev, junior scientific worker Petr Stepanovich Klochan, Institute of Cybernetics, Ukrainian SSR Academy of Sciences, and senior engineer Vasiliy Nikolayevich Lavrent'yev, Institute of Cybernetics, Ukrainian SSR Academy of Sciences]

[Text] The ATsP-35 adaptive converter developed at the Institute of Cybernetics, Ukrainian SSR Academy of Sciences, is designed for multichannel conversion of positive and negative polarity DC voltages to binary digital code and for entry of it to a digital computer using standard integraters of type RANG-2K, YeS-EVM [Unified Computer System] and so on. It is used in automation of scientific experiments and measuring-test work, in industrial monitoring systems, hybrid computer systems and information-computer complexes.

The device is designed on the modular principle and consists of the baseline version and additional units. An external view of the ATsP-35 is presented on the second page of the cover. Operation of the converter is organized by the digit coding method with two-way equalization of the signal to be converted. The presence of additional units in the converter permits automatic matching of the outputs of analog sensors to the input of the converter in the voltage range of 0-100 V, makes it possible to reduce the aperture time of the converter to 1 μs, to provide a general and normal noise suppression coefficient of not less than 120 dB and it also permits one to monitor, tune and calibrate the converter parameters during operation. The property of adaptation includes the capability of changing the number of digits from 10 to 16 and accordingly the conversion time from 5 to 10 μs, which permits optimum utilization of the parameters of conversion accuracy and speed in different systems. A block diagram of the ATsP-35 is presented on the third page of the cover. Here 1 is a multichannel commutator, 2 is a reference voltage source, 3 is a digital-analog converter, 4 is a comparator, 5 is a display unit, 6 is a number register, 7 is a control and monitoring unit and 8 is the interface.

The ATsP-35 converter differs from similar devices by structural homogeneity, accuracy, economy and high speed due to the use of original engineering solutions. The number of control members and regulations is reduced to a minimum by introducing a monitoring device and automatic correction circuit. The presence of digital display permits the ATsP-35 computer to be used in the voltmeter mode.

Main Specifications

Operating principle	Digit encoding
Number of connected analog channels	16
Input voltage range, V	
main	0-±10
auxiliary	0-±0.1; 0-±1; 0-±100
Number of digits of output code	10-16
Resolution, μV	150
Conversion error (corresponding to output code), percent	0.1-0.005
Linearity error, percent	0.0015
General and normal noise suppression coeffficient, dB	120
Conversion time, μs	5-10
Aperture conversion time, μs	1
Code output frequency, kHz	75-150
Consumed power with voltage of 220 V, frequency of 50 Hz, W	150

The ATsP-35 converter in standard ASVT-M housing measuring 480 X 485 X 160 is based on serially-produced integrated circuits.

The weight of the converter does not exceed 20 kg.

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SOFTWARE

PRACTICAL COURSE IN PROGRAMMING FOR M5000 SERIES COMPUTERS

Moscow PRAKTIKUM PO PROGRAMMIROVANIYU DLYA EVM SERII M5000 in Russian 1981 (signed to press 27 Apr 81) pp 2-5

[Table of contents, annotation and introduction from book, "Practical Course in Programming for the M5000 Series Computers", by Ol'ga Mikhaylovna Mitsuk and Yevgeniy Ivanovich Nikol'skiy, Izdatel'stvo "Finansy i statistika", 12,200 copies, 176 pages]

[Text]

Contents

Annotation

This practical course in programming contains examples of programs compiled in the Assembler, COBOL and RPG languages.

Attention is paid to the rules for using DOS components and to operating with general-purpose subroutines. The program examples can be used as fragments of larger programs.

The practical course can be used in a system for training personnel for computer centers, as well as by computer center employees, students, engineers and economists specializing in the field of processing economic information by applying M5000 series computer complexes.

Introduction

The development of information processing hardware in our country and abroad in rates of development is outstripping the development of software for it. After the first modification to the M5000 perforated computer complex (PVK), series production of which began in 1974, domestic industry set up production of its successors: the M5010 VK and the substantially improved M5100 VK.

M5000 series computer complexes are small third-generation computers with modern architecture, magnetic disks and tapes used as external storage and standard peripherals and are made with a modern element base.

The M5000 series VK are controlled by the disk operating system (DOS), designed to extend its hardware capabilities and which is a characteristic feature of all modern computers. The operating system is a set of software facilities that allow automation of the process of compiling application programs and execution of them on the computer; the facilities also control equipment during job execution.

The M5000 series computer complexes are upwards compatible computers, i.e. the software developed for the smaller computers can be used for the subsequent modifications. This circumstance large balances the priority in development of the hardware itself comapred to the software for each new modification of the M5000 series VK.

Both systems and applications software is being built up from model to model; and DOS itself continues to be improved. In addition to the Assembler system, the use of new facilities for automating rpogramming, the algorithmic languages, was begun. Translators have now been implemented for COBOL, RPG and PL/1 (first version).

Methods of programming with algorithmic language facilities are given in the "Practical Course in Programming for M5000 Series Computers." The orientation of the M5000 series computer complexes to the processing of economic information has determined the set of programming languages for the inclusion of them within DOS.

Each algorithmic language, besides general-purpose, is oriented to a certain class of problems, and it is for this class of problems that the highest efficiency of use of all its capabilities is achieved.

This practical course has a number of examples using general-purpose subroutines that are in DOS and delivered to users with the equipment. Using general-purpose subroutines considerably facilitates the process of compiling programs by freeing the programmer from many routine operations. A programmer can call them when writing programs in Assembler, COBOL or RPG. These general-purpose subroutines include a complex of subroutines intended for recoding of information prepared in accordance with various GOST [state standards] into the M5000 internal code and vice versa.

The M5000 series VK internal code is a code for representing information in accordance with GOST 13052-74 and meeting the requirements for computer processing of information.

Other standards are used for external media of information: information on punched cards can be prepared in accordance with GOST 10859-64, NPTO [expansion unknown] code 019.001 or GOST 19769-74; information on punched tape is coded in accordance with GOST 15029=69, GOST 10859-64 and MTK-2M code.

The M5000 series VK DOS contains, besides that of the GOST named above, subroutines for recoding information into the code used in the Unified System of Computers, the DKOI [decimal code for information interchange] (GOST 19768-74).

Among the general-purpose subroutines is a whole spectrum of routines designed to sort and merge files. Part of these subroutines can be used to generate working sort and merge programs, and part for arranging records in alphabetic order, etc.

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To supplement the practical course [5], this work contains examples in the machine-oriented language Assembler, which illustrate operation with magnetic tapes and with information represented in accordance with the different GOST's and other peculiarities in the use of this language.

The capabilities of dividing a program into parts, sectioning it, are pointed out. The process of sectioning is convenient and sometimes even necessary when large and complex programs have to be written. Examples are used to also illustrate the the capability of making use of a common area, or common program section, for communication between separate modules of a program.

This practical course also contains problems executed in the procedure-oriented general-purpose language of COBOL (or Common Business Oriented Language). COBOL is intended for problems that entail organization and processing of large data files, as well as for cyclic repetitive operations of data processing that are typical of business and economic problems.

Using COBOL presupposes a description of processing by a certain scheme:
identification, or title, of the process;
instructions on the computer equipment that msut be used in processing;
instructions on the data structure and nature of the data to be processed; and
descriptions of the operations on the data.

In accordance with this processing scheme adopted in COBOL, a working program includes: the identification division, the environment division, the data division and the procedure division.

The COBOL translator is based on application of the standard version of the language. The COBOL input language may use both Russian and English mnemonics. As an aid for studying the COBOL system, we recommend [4].

The problem-oriented RPG (Report Program Generator) language is a programming system designed to create data processing programs to format output files and reports. It was developed by breaking the process of data file processing into a number of typical operations that are executed formally and uniquely irrespective of the data content.

Such operations are:
searching records in a file for specified values of fields;
selection of individual records for their rpocessing;
execution of operations on fields in records;
adding new records to files; and
formatting output reports using specific forms.

The algorithm for data processing in an RPG program is not directly described; it is generated by the compiler according to a standard scheme that is executed under the control of the operating system. In this practical course, there is a chapter containing examples for using RPG in its specific implementation for the M5000 series VK.

There are two versions of RPG translators in the M5000 software. One version is described in detail in [3], and the other, developed by the SKB VM [Special Design Office for Computers], is described in [1]. The latter version of the translator has been illustrated by examples in this course.

Explanations for certain functions implemented in the examples are given in the course as supplementary information.

It goes without saying that before setting about solving the problems in this course, one must study the technical documentation on the software for the M5000 series computer complexes [1] and other literature (see the list of recommended literature at the end of the book)

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MANUAL FOR KOMPAS DATA BASE MANAGEMENT SYSTEM

Moscow RUKOVODSTVO PO SUBD KOMPAS in Russian 1981 (signed to press 9 Mar 81) pp 2-4, 44-46

[Annotation, table of contents, introduction and references from book, "Manual for the KOMPAS Data Base Management System", by Viktor Ivanovich Filippov, edited by V. M. Kurochkin, candidate of physical and mathematical sciences, Vychislitel'nyy tsentr Akademii nauk SSSR, 400 copies, 47 pages]

[Text] This manual covers the basic capabilities of the KOMPAS data base management system [DBMS] developed in the USSR Academy of Sciences Computer Center and based on the suggestions by the CODASYL [Conference on Data Systems Languages]. The system supports creation, maintenance and use of data bases through the programming languages in the DUBNA monitor system or directly through the interactive module for terminal access. The system version described is version 1.1 (January 1981). The manual is intended for KOMPAS DBMS administrators and users.

Contents

Introduction

The KOMPAS DBMS is intended for definition and management of structured data files (data bases) on the BESM-6 computer under DISPAK OS. The system can be used to design banks of data of any structure and sizes for information-reference and accounting-calculation systems, planning systems, computer-aided design systems (industrial and regional), application program packages, etc. In view of the availability of terminal access facilities, the system can perform the functions of an independent "adjustable" information-reference system.

The KOMPAS DBMS is based on CODASYL suggestions [1, 2, 3] (i.e. it can operate with any network structures of data), but does not implement these suggestions to the full extent, though in certain properties it goes beyond them. In subsequent versions, the system will be developed, on the one hand, in the direction of approaching the CODASYL suggestions, and on the other, on the level and amount of services offered the users.

In data structure and certain functional capabilities, the KOMPAS system is close to its predecessor, the AL'MA system [4, 5], but differs considerably from it in methods of implementation, general architecture and capabilities, interaction with inclusive programming languages and format of language facilities.

Contained in this manual are the descriptions of the system language and program facilities, recommendations for their use and instructions on the composition of the system version being sent and on placing it into operation. The size of this manual does not allow giving a sufficiently complete example of use; therefore, the texts of the data base example delivered with the system are being made available directly by the developer as separate Appendices. The developer is also making available current ATsPU [alphanumeric printer]-instructions for the KOMPAS system and the ATsPU-instructions for the universal DUBNA-interface with the MARS-6 system and for the MARS-6 system.

The language and program facilities in the KOMPAS system are rather standard, so that this manual can serve as a brief "Introduction" to the CODASYL suggestions on management of data bases. On the other hand, for a fuller understanding of the historical grounds and methods of using the suggested facilities, KOMPAS system data base administrators should refer to the basic texts for the CODASYL suggestions and works dealing with data base design.

To supplement the capabilities described here, development is now underway on facilities for logging, restructuring, automatic generation of load programs and a relational interface with the KOMPAS system.

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CSO: 1863/93

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EQUIVALENT TRANSLATIONS OF DATA STREAM SCHEMES

Kiev EKVIVALENTNYYE PREOBRAZOVANIYA SKHEM POTOKA DANNYKH in Russian 1981 (signed to press 21 Apr 81) pp 2, 45-46

[Annotation, conclusion and references from Preprint 81-24, "Equivalent Translations of Data Stream Schemes", by Viktor Ivanovich Borisenko, Institut kibernetiki Akademii nauk Ukrainskoy SSR, 300 copies, 48 pages]

[Excerpts] Annotation

One of the models of parallel programming is considered: data stream schemes suggested by Dennis et al. A system of translations is constructed that maintain the property of strong similarity and permit varying the asynchronous nature of the scheme and representing it in some standard form.

This work is of interest to specialists in the theory of programming and developers of operating systems for multiprocessor computers.

11. Conclusion

The system of translations suggested in this work permits considerable rearrangement of the informational portion of the scheme, varing the asynchronous properties of the scheme or reducing it to some standard form. For a certain class of schemes, this standard form is the natural form that permits obtaining the encessary condition of strong similarity of the schemes and, consequently, the necessary condition of their functional equivalence.

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UDC 681.03.06

DICTIONARY-DIRECTORY SUBSYSTEM FOR AUTOMATED SYSTEM FOR PROCESSING OF TEST RESULTS

Kiev PODSISTEMA "SLOVAR'-SPRAVOCHNIK" AVTOMATIZIROVANNOY SISTEMY OBRABOTKI REZUL'TATOV ISPYTANIY in Russian 1981 (signed to press 19 Feb 81) pp 2-4

[Annotation and excerpt from Preprint 81-2, "Dictionary-Directory Subsystem for Automated System for Processing of Test Results", by Vladimir Il'ich Skurikhin, Valentin Grigor'yevich Kvachev and Yuriy Romanovich Val'kman, Institut kibernetiki Akademii nauk Ukrainskoy SSR, 300 copies, 37 pages]

[Excerpt] Annotation

A problem-oriented dictionary-directory is considered for an automated system for processing of test results. Five functional subsystems are included in the dictionary-directory system described: informational support, mass input of information, report generation, interactive mode and interface facilities. The system described is implemented on the base of the SEDAN data base management system.

Using the dictionary-directory in designing large data processing systems provides the necessary service for administration of the systems under development. This work is oriented to a broad group of developers and designers of automated information processing systems.

The complexity of data structures, the diversity of forms for representing and methods of obtaining data, multipurpose utilization, the varying functional orientation of data processing programs, the variety of tasks being solved and the rather large data processing systems lead to the necessity of automating the work of administering such systems. This is a main reason for using dictionaries-directories in automated data processing systems. In [1], the data dictionary has been called the cornerstone of good data management.

A dictionary-directory system, on the one hand, is a "directory" in the sense that it enables answering the question: What is in a given system? This question breaks down into a set of questions:

what kind of data is kept in the system
what is their structure
in what formats are they stored
which programs use the given information
which programs are part of a given subsystem, etc., etc.

On the other hand, a dictionary-directory system is a "dictionary," since it permits answering the question: Where is a given item of information stored?

The need for dictionaries-directories arose back in the early stages of development of alrge data processing systems. Thus, to support flexible operation with a YeS OS data set, a table of contents was created on direct access volumes. Then for data base management systems (SUBD), tables emerged in the role of dictionaries-directories; these tables were created by using a data description language and formed a nucleus for programs that support language interfaces. These were all prerequisites for the emergence of a dictionary-directory system. However, these developments could not be considered dictionary-directory systems for the following reasons.

First, the main users of such catalogs, tables of contents and tables were programs oriented to execution of specific functions. Therefore, on the one hand, and this is the main thing, stored in such systems was only the data needed for programs, and on the other, it was stored in the corresponding formats.

The information stored in these dictionaries was clearly inadequate for system administrators in decision making.

Second, all the dictionary systems developed were oriented to solving a specific problem and were different.

The need for combining them into a single system, inherently, also led to the development of the dictionary-directory system. A survey of a number of these foreign systems was given in [1].

In contrast to systems of general-purpose dictionaries [1], in this work we consider a dictionary-directory oriented to application in automated systems for processing of test results (ASORI).

The data dictionary-directory is a metadata bank. It stores information concerning declarations of the data base, references of programs to objects of the data base, statistics on usage pertaining to access to the data, declarations of secrecy, etc.

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CSO: 1863/94

NEW PRIZ AUTOMATED PROGRAMMING SYSTEM

Moscow INSTRUMENTAL'NAYA SISTEMA PROGRAMMIROVANIYA YeS EVM (PRIZ) in Russian 1981 (signed to press 21 Aug 81) pp 3-9, 157-158

[Introduction, chapter 1, bibliography and table of contents of book "The PRIZ Instrument System of Programming YeS Computers", by Mil'vi Iokhannesovna Kakhro, Akhto Peeterovich Kal'ya and Enn Kharal'dovich Tyugu, Izdatel'stvo "Finansy i statistika, 15,000 copies, 160 pages]

[Excerpts] Introduction

It is difficult to give an exact definition of the concept of a "programming system." At the present time the role of the programming system as the aggregate of means for development of computer programs is steadily growing. As the speed of computers is increased it becomes increasingly possible to automate programming. High-level programming systems in which the computer is an intellectual partner of the programmer have become widespread today. Among these systems is the PRIZ YeS, which differs from most other high-level programming systems in that it is an industrial, not an experimental, system. This system has two prototypes, the SMP and PRIZ-32 systems which were tested on a Minsk computer. The PRIZ system has been used for a fairly long time and is now being distributed by the Algoritm Science-Production Association as a component of the software of the YeS EVM [Unified System of Computers].

This book describes the capabilities and conceptions of the PRIZ system, its input language, and programming technology in this system. The book is intended primarily for programmers who are developing specialized programming languages and translators, program packages, and large program complexes. The first chapter, which reviews the basic concept, purpose, and capabilities of the system, and the last chapter, which presents an example of a program package, will also be interesting to specialists in the applied areas who have an interest in the construction of program packages.

The book also contains material on the realization of new concepts. Because this system employs automatic program synthesis on a broad scale for the first time, the description of certain principles of realization may be interesting for system programmers and specialists in translators.

The authors have attempted to present the material in the book in such a way that the reader will not need specialized knowledge in system programming.

Chapter 1 was written by E. Tyugu, while Chapter 3 was written by M. Kakhro, and Chapter 5 by A. Kal'ya. The bulk of the material in the book is the joint work of all three authors.

Chapter 1. Purpose of the System. Basic Concepts.

The Place of the PRIZ System in the Software System of the YeS EVM

The software system of the Unified System of Computers (YeS EVM) is an extremely large complex of programs designed for computer operations and the development of new programs. The basic principle in program development is the modular principle, which makes it possible to compile and process pieces of a program of the necessary dimensions (modules) independently of one another.

It can be said that the YeS EVM software supports the technology of modular programming. Work on structuring a program is essentially work on its modules. Each of them goes through certain stages of processing, input, text generation, text editing, translation, linkage editing, loading, and starting. During this the form of the modules changes from the initial module recorded in a certain input language to the object model (result of translation), and finally to the loading model, ready for execution.

YeS computers permit storing a practically unlimited number of modules in libraries on magnetic disks. But it is becoming increasingly difficult to keep track of the large number of modules, select the needed ones from them, and assign the information necessary to join them into a single program. Moreover, when constructing a new program from ready modules it is almost always necessary to devise a certain number of new, and almost always very small, pieces of programs, in other words modules to interlink the already existing ones. These linkage modules may be required to transfer data, convert format, convert units of measure, and for other purposes. The PRIZ programming system contains means to automate the selection of modules and automatically construct modules for interlinking other modules.

An important feature of this system is its complete compatibility with the processing programs of the YeS operating system, with translators from FORTRAN and COBOL, and with the macroassembler. We should note that compatibility here means that the PRIZ system does not impose any additional limitations on the modules. It can be considered an expansion of the YeS operating system which provides new means for processing modules.

Figure 1 below shows the relationship of the PRIZ system to components of the YeS operating system and ways of using it. Programming in FORTRAN or in the Assembler language (lines 7 and 6 in Figure 1) requires the use of the linkage editor to obtain a loading module and operating system for starting the programs. Programming using the PRIZ system always requires, in addition, use of the Assembler language to obtain object modules. There are different possible variations of combined use of the programming system:

a. programming in FORTRAN using expansions of the language in the form of job statements (8);

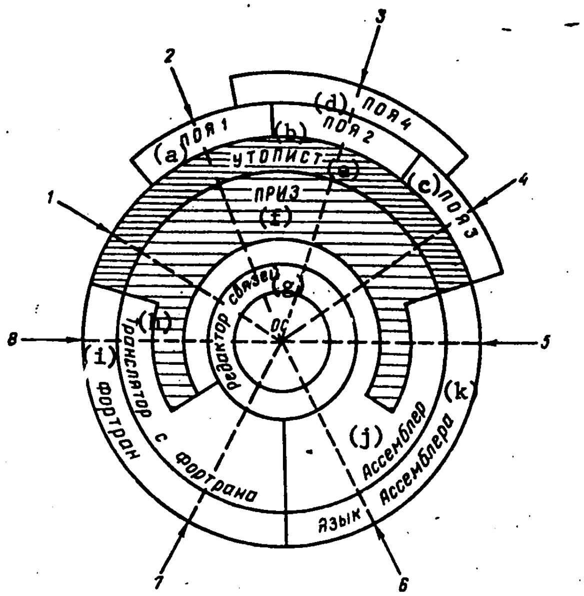

Figure 1. Relationship of the PRIZ System with YeS EOM Software

Key:
- a. Package Input Language 1;
- b. Package Input Language 2 ;
- c. Package Input Language 3;
- d. Package Input Language 4;
- e. UTOPIST:
- f. PRIZ
- g. Linkage Editor;
- h. Translator from FORTRAN;
- i. FORTRAN;
- j. Assembler;
- k. Assembler Language.

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b. programming entirely in the input language of the PRIZ system 1;

c. solving problems written in the package input languages of the applied programs, which are constructed by means of the PRIZ system (2-4);

d. programming in Assembler language using expansions of the language in the form of job statements (5).

Another permissible application of the system is where some of the modules are written in FORTRAN, some in ASSEMBLER, and some in COBOL.

Compatibility with PL/1 language is not specially provided in the PRIZ system because the translator from this language outputs object modules that are difficult to combine with modules obtained from other languages. But it is possible, using procedures described in instructions for programming in PL/1, to use modules obtained from this language.

In the programming systems of the YeS operating system it is necessary to explicitly indicate the modules in the request for a subroutine or macrooperator in order to combine modules into a single program; but the PRIZ system in many cases eliminates the need for explicit indication of the modules which must be joined in the final working program. Therefore, the system user is largely freed from programming, but has the duty of describing the job conditions and on their basis the program is automatically synthesized. Obviously, the correctness of the program is then determined entirely by the correctness of the assignment conditions, because the automatic program synthesizer does not make errors. This greatly increases the productivity and quality of programmer labor, in other words it raises the technological level of program development for YeS computers.

The PRIZ as a System for Construction of Translators

In 1968 D. Knuth proposed representing the semantics of programming languages by attributes ascribed to language symbols and relationship assigned among attributes [1]. This technique, called the attribute technique, is now the most common method of automating construction of the semantic part of translators. In practice, however, it does not provide fully automatic construction of the translator with respect to description of semantics. In the first place, know-how in defining appropriate attributes and relationships for all the constructions of programming language is still not widely enough distributed. In the second place, the attribute technique itself has certain problems in organizing computation of the values of the attributes [2].

The PRIZ programming system also permits defining the semantics of concepts (that is, nonterminal symbols) of new languages by describing the corresponding attributes, called their components, and the relationships among components, which permits organizing computation of the latter.

In this sense, there is a full analogy between the attribute technique proposed by D. Knuth and the semantic models technique used in the PRIZ. The main difference is that the PRIZ system is applicable to write new problem-oriented languages as expansions of the one base language, UTOPIST. Unlike most of the systems for construction of translators, it uses the macrogeneration technique for syntactical text processing instead of syntactically controlled analysis. The principal advantages of the system are powerful and convenient means of semantic processing and simple-to-use syntactical means. This allows extremely quick construction of translators for many simple languages.

The PRIZ as a System for Construction of Program Packages

Development of a package of programs differs so greatly from development of an individual program that expertise accumulated by programmers solving applied problems is plainly inadequate to construct a package that functions well.

Both specialists in the subject area and system programmers must participate in construction of a package. Specialists in the subject area of the package are responsible for correct selection of the concepts of the input language of the package and for choosing computing techniques which are adopted as the basis for programming modules of the package. The work of specialists in the subject area during construction of the package is ordinarily called modular analysis. This is the first stage of program construction. Modular analysis may result in a design for a program package.

System programmers are responsible for good-quality realization of the package design. Ultimately they must put the package under development in the form of a finished program product which meets very high quality specifications.

It often happens that applied specialists undertake the development of a package of programs without the participation of system programmers. The thing to be feared in this case is that the program package will take the form of a partially operating model of the conceived system. Development of the finished program package is postponed for an indefinite time because of unforeseen difficulties that arise in the concluding stage of work. The same difficulties are observed when a program package is developed by system programmers without participation by adequately qualified specialists in the applied subject area. In this case there may be a danger that the class of jobs to be done as selected by the designers of the package will not satisfy package users and the problem-solving techniques will be ineffective or limited in applicability.

A quality package can only be developed by clearcut work procedures supported by appropriate software. The PRIZ system is a system for constructing program packages that insures all the basic stages of package development:

a. modular analysis;

b. programming, debugging, and testing the program modules included in the package;

c. designing and realizing the input language;

d. development of the control part, that is, the part that organizes the programs of the package;

e. providing the services necessary for work with the package (communication with the data base, input-output, and dialogue).

For modular analysis the PRIZ system has means to formalize the description of system models and processes from the most diverse areas. It provides the capability of automatic processing and storage of formalized descriptions.

For the second stage, programming modules, COBOL, FORTRAN, and MACROASSEMBLER are applicable and there are expanded capabilities for including automatically synthesized parts of the programs.

Nonetheless, these two stages are least subject to automation because they require knowledge of a specific subject area, and the main difficulty is not machine realization but making correct content-oriented decisions.

The remaining stages beginning with realization of the input language are very highly automated in the PRIZ system. Chapter 4 presents the work procedures for construction of packages.

The PRIZ as an Artificial Intellect System

In the second half of the 1970's a trend was clearly observed to use artificial intellect methods in practical applications.

In translators and programming systems application of these methods is promising for raising the level of the language in which dialogue with the computer is conducted. This refers to both programming languages and specialized languages for job descriptions.

The PRIZ system uses the following procedures from the field of artificial intellect.

1. The semantics of the input language are described in semantic models that contain objects and relationships. Processing of the initial text involves translating it into semantic notation and working with semantic models.

2. A very convenient possibility is created of expanding the input language by describing new concepts through existing ones in the same way as is done in other artificial intellect systems. Semantic memory and resources for working with it are used for this purpose.

In fact, work is organized with concept frames, that is, semantic models in which significant changes are made automatically to adjust to a concrete situation (use of objects of the NEOPR' type) and make it possible to perform the necessary procedures automatically (without an explicit call).

3. It realizes automatic program synthesis and creates possibilities of solving problems based on their assigned conditions.

On the other hand, experience has shown that the PRIZ system is very applicable to program jobs for an artificial intellect. Specifically, using it one can quickly set up machine experiments to form concepts, teach, use unclear concepts, and the like which formerly took much more time.

Technological Services of the System

In addition to the primary functions performed by the PRIZ system, the user can receive the following services from it.

1. Virtual memory programs which can be used in modules written in FORTRAN or ASSEMBLER language permit work with a large-volume mathematical memory, automatically replacing pages from disk memory.

2. The dialogue regime of program translation and generation permits direct contact between the user and the system.

3. Work directives with semantic memory are more convenient for work with a library of models than means for work with library files.

4. The HELP information program is designed to receive operational information on expansions of the UTOPIST language.

5. High-level debugging resources permit automation of comprehensive debugging of synthesized programs taking into account possible errors in modules and descriptions of job conditions.

6. The system has a set of catalogue procedures which permit work in various regimes: batch processing and dialogue; the regime of expansion and modification of the model of the subject area; the macrogeneration regime; the regime for solving problems written in the input languages of the packages; the regimes for solving problems which are described in FORTRAN or ASSEMBLER language and so on.

7. There are special utilities that insure convenient management of the libraries of semantic models and the macroprocessor of the PRIZ system.

8. The package of applied programs for data base control systems is compatible with other packages designed in the PRIZ system, which enables users of the system to construct individual data bases.

9. The generator of dialogue programs permits generation of dialogue modules that are included in the program packages.

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MANUAL ON SWITCHING TO MORE POWERFUL YeS OPERATING SYSTEM

Moscow PEREKHOD OT DOS YeS K OS YeS (SPRAVOCHNOYE POSOBIYE) in Russian 1980 (signed to press 11 Aug 80) pp 2-4, 226-231

[Annotation, foreword, bibliography, and table of contents of book "The Transition From the YeS Disk Operating System to the YeS Operating System (Reference Manual)", by O. S. Ivaniko, N. M. Ivanyutina, M. P. Kotov, T. P. Potapenko, L. M. Romanovskaya and A. T. Fedorov, Izdatel'stvo "Statistika", 29,000 copies, 232 pages]

[Excerpts] Anr tation

This book reviews the basic differences between the YeS DOS [Unified System Disk Operating System] and the OS YeS [Unified System Operating System]. Recommendations are given on converting DOS YeS programs and files for use in the OS YeS.

The manual is intended for users of the DOS YeS who are planning to switch from operations using the DOS YeS to operations using the OS YeS.

Foreword

The software of YeS [Unified System] computers includes two operating systems, the DOS YeS (DOS) and the OS YeS (OS). These systems accomplish the same purposes: raising the efficiency of use of YeS computer hardware and increasing the labor productivity of programmers and service personnel. In many respects the means by which these objectives are accomplished are the same: processing, multiprogramming, programming languages and corresponding translators, data control means, and the like.

The concrete realization of these means in different operating systems is determined by the orientation of the system to configurations of computing machines that differ by power . Thus, the DOS is oriented mainly to small YeS models and takes account of the limited capabilities of the hardware of these models (small internal memory volume, low processor speed, and the small set and limited types of peripheral units usually connected to these models). The OS operating system offers users a significantly more powerful hardware configuration.

Theoretically the OS and the DOS can function on any of the YeS models with the exceptions of the YeS-1010 and the YeS-1021. The appropriate operating system is chosen applicable to the specific purpose of the YeS machine at the computing center. As things developed historically, however, the DOS operating system was most widely applied in the first phase of development of YeS computers. This was because its development and delivery preceded that of the OS by 2-3 years and owing to the limited configuration of the first models of YeS computers. Broader use of the DOS was promoted by its simplicity, which insured comparatively rapid incorporation of the system.

In recent times users have reoriented themselves to the OS as a result of the following factors:

- the new models appearing in the Unified System of computers are significantly more powerful than the first models;
- the configurations of already-installed computers are being expanded by connecting in additional equipment;
- most of the packages of applied programs are oriented to the OS;
- users are developing a need for the additional capabilities offered by the OS.

Analysis of these factors permits us to conclude that most users of the DOS today will in the near future face the question of switching to use of the OS. The incompatibility of the DOS and OS operating systems makes this transition a fairly difficult job. Among the basic factors that make the transition from the DOS to the OS difficult are the following:

a. It is not possible to exchange programs between the operating systems in formats that are the result of translation (object modules) and editing (absolute modules for the DOS and loading modules for the OS). This exchange is impossible primarily because the interface between problem programs and the control program is realized differently in the system, and so the processing of SVC statements by which many of the system functions are requested is completely different;

b. Without preliminary analysis and, in a large majority of cases, without additional processing it is impossible to exchange programs in source languages. The labor-intensiveness of such processing depends on the programming languages and the programs in these languages. For Assembler language it is very significant, while for high-level languages it is less significant. This difference in labor-intensity occurs because users of the DOS and OS are given substantially different sets of system macroinstructions without which no program in Assembly language can get by;

c. It is impossible to exchange prepared assignments between operating systems because of differences in assignment control languages;

d. Data files prepared on magnet media in the DOS cannot always be used directly by programs in the OS. In some cases preliminary conversion of the files is required to use them in this way.

Two primary stages can be identified in the transition from the DOS to the OS: evaluating the wisdom of making the transition for the particular computing center, and organizing work to carry out the transition.

In the first stage it is necessary to evaluate: the capabilities offered by the OS and the need for them to solve user problems; the availability and prospects for receiving the hardware necessary for efficient operation of the OS; and, external factors that stimulate use of the OS. These factors are then compared with the labor-intensiveness of switching to the OS. The material presented in the book will enable the reader to compare the capabilities of the DOS and OS and to get some idea of the labor-intensiveness of the transition from the DOS to the OS.

After making the decision that the transition to the OS is necessary, study of this operating system should be organized. This book can provide introductory material for studying the OS. The book reveals the functions of the OS by comparing them with the functions of the DOS, which makes it easier for a reader familiar with the DOS to understand the basic principles of the OS.

The main purpose of this book is to give concrete recommendations on converting programs, assignments, and data files accumulated in the process of using the DOS for subsequent use in work with the OS.

The book does not consider questions related to remote processing. The material presented in the book corresponds to publications 2.2 DOS YeS and 4.1 OS Yes.

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OPTICAL PROCESSING

APPLICATION OF OPTICAL INFORMATION PROCESSING METHODS AND HOLOGRAPHY

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 1-2, 436-441

[Annotation and table of contents from book "Application of Optical Information Processing Methods and Holography", a collection of the papers read at the Third All-Union School on Optical Information Processing Methods held in Riga in May 1980, edited by Professor S. B. Gurevich and V. K. Sokolov, candidate of physico-mathematical science, USSR Academy of Sciences, Order of Lenin PhysicoTechnical Institute imeni A. F. Ioffe, LIYaF [Leningrad Institute of Nuclear Physics imeni B. P. Konstantinov], 500 copies, 442 pages]

[Text] Annotation

This is a collection of the papers read at the Third All-Union School on Optical Information Processing Methods held in Riga in May 1980.

The collection is divided by subject into three parts: optical methods of image processing (including problems of practical use), spatial-time light modulators and recording media and optical methods of signal processing. Both survey papaers and results of original research are presented on these problems.

To a certain extent, this collection reflects the state-of-the-art in optical processing of information and its element base at present. It will be of use to a broad group of specialists working in the field of optical processing of images and signals and its applications in various fields of science and technology.

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Part 3. Optical Methods of Signal Processing

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SPATIAL-FREQUENCY SPECTRA OF IMAGES OF DISTURBED WATER SURFACE

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 137-140

[Article by A. I. Balabanov, S. S. Bogdanov, V. A. Skorik and A. A. Feoktistov]

[Text] Annotation

Experimental research performed permits picking out spectral features of presence of systems of waves distinguished by their parameters (general directions, length of waves and others) and gives an idea of the statistical stability of the characteristics of waves obtained in coherent optical processing of aerial photographic and radar images.

Coherent optical processing of photographic images of a disturbed water surface is one of the more promising methods of statistical analysis of wave characteristics [1].

To process photographic images of a disturbed water surface, we used an optical electronic system for generating spatial-frequency spectra (PChS) (fig. 1).

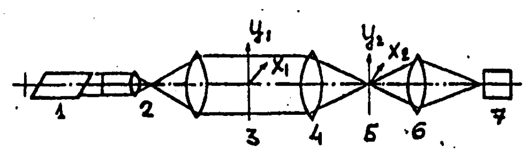

Fig. 1.

The device includes the He-Ne laser (1), the beam broadening system (2), the Fourier transforming lens (4) and the photo detector (7). The laser beam, passing through the beam broadening system, illuminates the image $E_1(x_1, y_1)$, placed in the front focal plane (3) of the Fourier transforming lens, the light amplitude.

$E_2(u, v)$ in the rear focal plane at an arbitrary point with coordinates x_2, y_2 is related to the light amplitude $E_1(x_1, y_1)$ in the front focal plane by the equation of the two-dimensional Fourier transform:

$$E_2(u,v) \sim \iint E_1(x_1,y_1)\, e^{-i(ux_1+vy_1)}\, dx_1\, dy_1 . \qquad (I)$$

The values of the components of the spatial frequency u, v are determined from the relations:

$$u = \frac{2\pi}{\lambda}\frac{x_2}{F}, \quad v = \frac{2\pi}{\lambda}\frac{y_2}{F},$$

where λ is the laser emission wavelength and F is the focal distance of the lens.

The spatial-frequency spectra is recorded by measuring the energy of the emission that has passed through the spectral window formed in the spatial-frequency plane (5) of the spectroanalyzer by using the slit and wedge-shaped aperture (5° aperture angle) in the opaque screen. When the slit is shifted, the window is shifted in a radial direction along the wedge-shaped aperture. The emission that has passed through the spectral window is projected by the collecting lens (6) to the photocathode of the FEU [photomultiplier]. Photo transparencies with fragments to be analyzed are placed in a rotating ring with the center of rotation on the optical axis. The energy that has passed through the emission window is measured by using the FEU and a recording milliampere meter. Results of measurements are recorded on tape, and recording tape movement is synchronized with the rotation of the photo transparency.

Both vertical aerial photographic images and radar images of a disturbed water surface, obtained by using side-looking radar [SLAR], were processed. Is is known [1] that the spatial-frequency spectra of vertical aerial photo images $|E^{opt}(u, v)|^2$ and of radar images $|E^{SHF}(u, v)|^2$ are related (in the corresponding scale) with the square of the modulus of the transformation of the Fourier-function of the relief of the disturbed water surface by the following relationships:

$$(1)\quad |E^{opt}(u,v)|^2 \sim (u^2+v^2)\,|S_x(u,v)|^2, \qquad (3)$$

$$(2)\quad |E^{SHF}(u,v)|^2 \sim u^2\,|S_x(u,v)|^2. \qquad (4)$$

Key:
1. E^{opt}
2. E^{SHF}

The appearance of the squares of the components of the spatial frequencies in the right portion of the expressions (3) and (4) is due to the fact that the amplitude transmission of the aerial photo and radar images is proportional not to the value of the water surface relief itself, but to the steepness, i.e. to the derivative of the wave relief according to the coordinates. And in the case of radar images, there is an isolated direction corresponding to the direction of illumination. In view of the narrow band of the spectrum of the disturbed water surface relief function $|S_x(u, v)|^2$, the spectral characteristics of the individual wave systems can be derived by measurements of the characteristics of the spatail-frequency spectra (see [1]).

Eleven aerial photo images of Lake Baykal obtained during one flight were subjected to coherent optical processing. The quality of them was not too high, because the waves were poorly developed and the presence of haze caused a sharp decline in resolution. Also, the degree of clearness of the image of the wave system varied sharply in going from one aerial photo to another and in going from one fragment to another within one aerial photo. Despite this, the position of the maximums in the image of the spatial-frequency spectra defines the general directions of propagation of the two wave systems and the wave lengths corresponding to them, $\lambda_1 = 6$ m and $\lambda_2 = 10$ m.

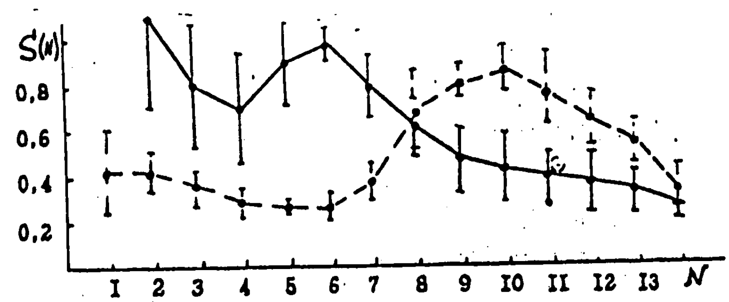

Fig. 2.

Fig. 2 shows the plots describing the radial distribution of the spatial-frequency spectra for the high-frequency wave system (VSV) and the low-frequency wave system (NSV) along the general directions of propagation. Plotted on the X axis are the distances from the center of the spatial-frequency plane to the center of each of 14 positions of the quantizing window. Plotted on the Y axis are radial sections of the spatial-frequency spectra, averaged according to individual realizations, and normalized at points corresponding to the wave maximum /I/.

Precision of measurements for the high and low frequency wave systems varies from 8% and 10-12% (in the areas of maximums of radial distributions) to 22 and 28% in the remaining portion of the spatial-frequency spectra.

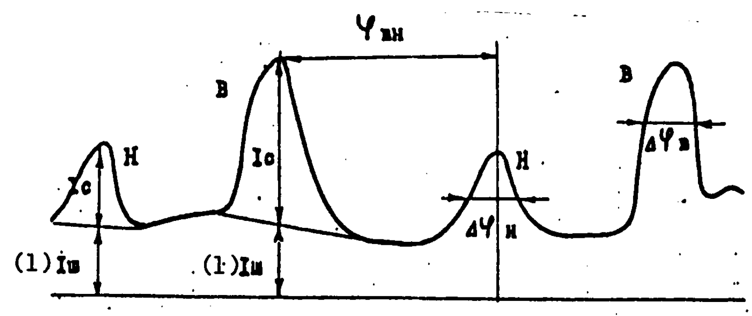

Fig. 3.

Key:
1. I_{sh}

Given in fig. 3 is a general view of the angular relationship of the integral angular spectrum. B and H denote the values pertaining to the high [B] and low [H] frequency wave systems. In a change in general direction of one of the wave systems relative to the other, the value of the angle between the high and low frequency maximums φ_{BH} changes. This provides the capability, after constructing a system of photo detectors for a certain spatial-frequency spectrum, of subsequently automatically recording the relative variation of the general directions of the wave systems and their other characteristics. In the process, obvious limitations on the precision of the method are imposed by the widths of the maximums and the signal-to-noise ratio. In our case, the average, by realizations, widths of the high and low frequency maximums (at a 1/2 level) are 21° and 31°, respectively, and the standard deviations are 8% and 28%. By realizations, the average signal-to-noise ratio, I_c/I_{sh}, for the high and low frequency maximums was 2.0 and 1.7.

In processing radar images, this technique permits picking out similar features describing the state of a distrubed sea surface.

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OPTICAL METHOD OF MEASURING DIMENSIONS OF MOVING OBJECTS ON BASIS OF SCATTERED WAVES

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 150-154

[Article by V. V. Vertoprakhov and Yu. V. Chuguy]

[Text] Annotation

A projection method is described for measuring the dimensions of moving objects based on scattering by objects of interference bands generated by two sloping beams of light. Object dimension is measured by calculation of number of interference bands within its shadow image. Results are given for research of an experimental system.

Actions of the majority of measuring systems are based on the principle of an optical measuring "rule," the role of which can be performed, for example, by a rule of photo diodes [1] and the band system in the Michelson interferometer [2]. Experience in developing such systems has shown that requirements imposed on them are internally contradictory.

In this work, we discuss a projection method for measuring object dimensions. In this method, high precision of measurement is achieved by applying an interference "rule" in the form of interference bands, and high productivity by using the light scattering effect of moving objects [3]. Measuring object dimension comes down to calculating the number of bands within its shadow image.

This organization of the measuring process provides system invariance to the rate of object movement, which to a certain extent permits overcoming the contradiction between accuracy and speed of the system. The value of the "rule" divisions is defined by the period of the interference bands, which can be brought down to several microns. System speed depends on the band counting rate, which can be tens and even hundreds of megaherz.

Let us discuss the dimension measuring method by the diagram shown in fig. 1. For the sloping coherent beams of light A and B, in the region of their intersection, there is formed an interference field, the band spacing period in which is $\Lambda = \lambda/2\sin\alpha$, where λ is the light wavelength and α is the half angle between beams A and B.

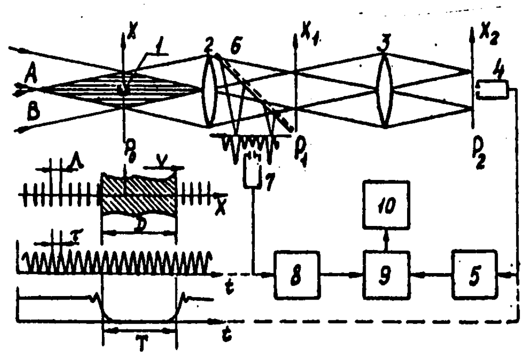

Fig. 1.

During movement of object I in this field, information on its dimension D and velocity V are recorded in two channels: the object (elements 2+5) and the measuring (elements 2, 6+8). Formed in the first channel by lenses 2 and 3 in plane P_2 is the shadow image of object I, which is analyzed by photo detector 4 with a point diaphragm. The signal output from the photo detector is converted by the amplifier-shaper 5 into an electrical strobe pulse, the duration T of which is determined by the object dimension and its velocity: T = D/V. As a result of the scattering of the interference bands by the moving object, a light flux is formed in the measuring channel that is time modulated. By using the beam splitter 6, this flux is followed by the photo detector 7 in the rear focal plane P_1 of lens 2. The modulation period τ of the measuring signal obtained equals the time of intersection by the boundary of the object of one interference band: $\tau = \Lambda/V$. The measuring pulses generated in unit 8 and the strobe pulse feed into the coincidence circuit 9 which forms an output burst, the number of pulses in which is $N = T/\tau$. By calculating the number N and multiplying it by the weight factor Λ, the dimension sought $D = N\Lambda$ is found in the computation unit 10.

It is evident that the error in measuring the dimensions depends both on the precision in shaping the strobe pulse in the object channel and on the period of the modulated light flux in the measuring channel.

Let us analyze the measuring signal under the assumption that beams A and B have a Gaussian distribution of the field with amplitude E_0 in the center of the beam. Then with modulation of the interference bands by the moving object I, the distribution of the field in plane P_0 along the x axis has the form:

$$f(x) = 2E_0 \cos(\omega_0 x)\left[1 - \mathrm{rect}\left(\frac{x - vt}{D}\right)\right] e^{-(x/\delta)^2}, \qquad (I)$$

where $\omega_0 = 2\pi \sin\alpha/\lambda$, δ is the halfwidth of the Gaussian beam in plane P_0 along the x axis and rect(·) is a rectangular function.

When the photo detector 7 with the point diaphragm is placed in the center of the frequency plane P_1, provided $\Lambda \ll D \ll d$, the measuring signal is proportional

$$I_1(t) = \frac{4}{\pi^2} E_0^2 \Lambda^2 \sin^2(\pi D/2\Lambda)[1 + \cos(2\omega_0 vt)] e^{-2(vt/d)^2}. \quad (2)$$

(The case of scattering of light on small particles $D \leqslant \Lambda$ is considered in detail in [3]). One can see that this signal, along with the low frequency component defined by the structure of the incident beams, contains a high frequency periodic component too. And its period τ is uniquely related to the period of the interference bands: $\tau = \pi/\omega_0 v = \Lambda/v$.

It follows from expression (2) that in the general case, the level of the signal $I_1(t)$ varies as Λ^2. Under certain relationships between the parameters D and Λ, this signal can become zero. These effects are significantly attenuated in the case of monitoring of bulky objects because fo the presence of waves reflected from their surface. Thus, for a cylinder, interference of the rays of the wave reflected from it leads to the occurrence of a travelling wave, the intensity of which does not depend on the relationship between the cylinder diameter and band period, but is proportional

$$\bar{I}(t) \sim [1 + \cos(2\omega_0 vt + \frac{2\pi}{\lambda F} x_1 D \cos\frac{\alpha}{2})] e^{-2(vt/d)^2}. \quad (3)$$

Since the measuring signal level depends in the general case on the interference band period, this produces a limitation on increasing the system sensitivity by reducing the band period. A promising way of increasing sensitivity is generation of a new measuring signal, the frequency of which is q-fold higher than the photo detector signal frequency, for example, by using an interpolator with phase automatic frequency control.

Experimental studies of a system, built on the basis of this method, consisted in evaluating the accuracy and productivity of a measuring system with the example of monitoring objects with known parameters, as well as in studying the criticality of its characteristics to variation of the basic parameters.

Used to calibrate the system was a reference cylinder with diameter D_0= 10·0412 mm, certified with an error of no more than 0.2 micrometer. Based on the derived value of Λ = 21.26+0.03 micrometer, the diameters of eight cylindrical rollers were measured (D = $\bar{1}$+16 mm), certified in advance with an error of 1 micrometer. The maximum error of the measurements did not exceed 20 micrometers.

The experiments showed that when the velocity varied within the range of 0.5 + 1.5 m/s, i.e. by $\pm$50% from the rated V_0 = 1 m/s, the value of the error in measuring remained unchanged. It should be noted that the permitted range of velocities V in the system was determined by the bandwidth of amplifiers 8 and 9 and could be extended when necessary.

Thus, the system developed permits determining dimensions of objects in the range 1 + 16 mm with an accuracy of 20 micrometers when their velocity of movement is 1 $\pm$ 0.5 m/s.

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OUTPUT UNITS FOR OPTICAL INFORMATION PROCESSING SYSTEMS BASED ON CHARGE-COUPLED DEVICES

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 169-174

[Article by V. A. Arutyunov, N. A. Yesepkina, B. A. Kotov, Yu. A. Kotov, A. P. Lavrov and I. I. Sayenko]

[Text] Annotation

Multielement photo detectors based on charge-coupled devices (PZS) [CCD] are considered. The design and features of operation of these photo detectors which have a varied organization and number of elements are described. It is shown that these photo detectors can be used as output devices for optical information processing systems, in particular, acoustooptic spectrum analyzers.

Optical information processing systems permit high rates in processing large arrays of data in real time. The processed data is contained in a spatial distribution of intensity at the output focal plane of an optical system. Various photo detectors are used to convert this data into an electrical signal. The choice of the photo detector governs the accuracy and speed of the system as a whole. The most promising photo detectors now are solid-state converters based on CCD [1, 2]. In the general case, a multielement CCD photo detector contains an array of photo sensitive elements (section for accumulation of charges) and shift registers (section for charge transfer). Photo diodes or capacitors may be used as the photo sensitive elements. They effect the conversion of a light intensity into a proportional quantity of an electric charge. The shift registers play the role of buffer storage and provide for serial travel of the obtained charge distribution to an output assembly. Thus, the shift registers permit easy joining of CCD to various devices, including computers [3]. The photo sensitive elements and shift registers are made in one structure on a base of a silicon chip.

We studied two types of linear photo detectors: with coincident and separate sections for charge accumulation and transfer.

Information charges in CCD with coincident sections for storage and transfer are stored by the same electrodes used for transfer. This combination of sections has become possible because of the application of transparent polysilicon electrodes that form the transfer channel. In these CCD photo detectors, constant levels of voltage are supplied to the various electrodes for the charge storage time to maintain the required potential profile under these electrodes. To read out information, the stored charge clusters are shifted to the output assembly. The shift is effected by feeding the appropriate pulse voltages to the phase electrodes. At output, we have a series of pulses that is a video signal. We studied two modifications of CCD with combined sections containing 50 and 500 light-sensitive cells.

The CCD photo detector with 50 cells is a linear four-phase shift register with a 32-micrometer cell arrangment step (image digitization step) [4]. The width of the light-sensitive area of the register is 1.5 mm, which permits integrating the light flux at one of the coordinates. At both ends of the register are charge detectors (charge-voltage converters) and output amplifiers. Output of information to any output device is possible as a function of the phase relationships of the control voltages. KMOP [CMOS] series integrated microcircuits are used in the register operation control unit. The control unit and CCD photo detector are made in the form of a unified module with dimensions of 8.5 x 10.0 cm^2, which is connected to a source of constant voltage of 6 + 18 V. Input at 10 V of supply voltage is 30 mW.

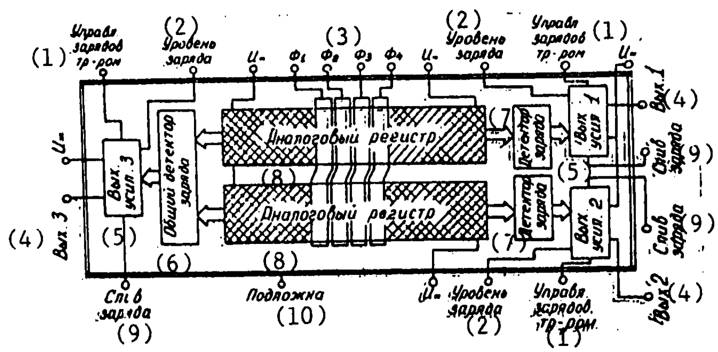

Fig. 1. Structural diagram of 500-cell CCD with coincident sections for storage and transfer

Key:

1. charge tr-r control
2. charge level
3. Fl, F2, F3, F4
4. output (1, 2, 3)
5. output amplifier (1, 2, 3)
6. common charge detector
7. charge detector
8. analog register
9. charge sink
10. substrate

Shown in fig. 1 is a structural diagram of a 500-cell CCD photo detector with combined sections for storage and transfer. This device has two four-phase analog registers with common phase electrodes. The cell digitization step in each register is 24 micrometers. The width of their light sensitivity range is 200 micrometers. Space between registers is 13 micrometers. Electrodes in the upper register are shifted relative to the electrodes in the lower register by 1.5 micrometers. On one side of the device, each register has independent charge detectors with output amplifiers. On the other side, there is a charge detector with its own output amplifier that is common to both registers. This design of this output assembly provides the capability of effecting a temporary "deposit" of signal information from both registers. With static distributions of light intensity and by using an appropriate algorithm for storage and multiple readout of information, this permits reducing the digitization step for the image being projected on the light sensitive surface of the CCD to 1.5 micrometers. In the process, the number of readout points can be increased from 500 to 8,000.

The signals output from these CCD's, corresponding to the maximum charge clusters, are not less than 3 V. CCD internal noise does not exceed 120 microvolts. Spectral range is 0.45 + 1.0 micrometer. Time for filling potential wells (storage cells) with dark currents is 10 + 50 s at room temperature.

The CCD photo detector with separate storage and transfer sections has 800 light sensitive cells and three sections differing in functional purpose: 1) separation of carriers, 2) storage and 3) analog register. Separation of carriers generated by light is performed by photo diodes 3 (fig. 2), the surface potential Ψ_s of which is determined by the surface potential under barrier electrode 3.

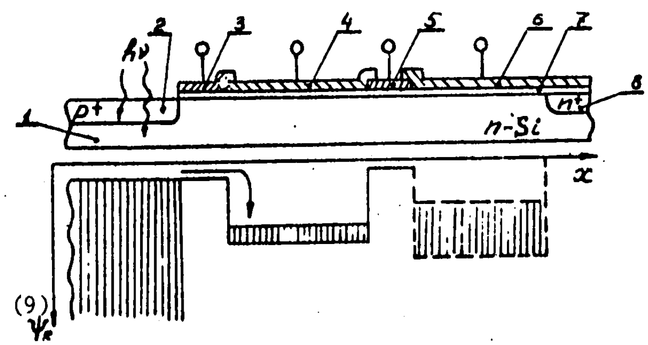

Fig. 2. Cross-section and voltage waveforms for CCD with 800 cells.

Key:

1. semiconductor substrate
2. photo diode
3. barrier electrode
4. storage electrode
5. separating electrode
6. analog register electrode
7. oxide
8. stopper diffusion
9. surface potential

Photo generated charges are stored under electrode 4. Upon completion of the storage cycle, the charges are transferred to analog (read) register 7 by using the separating electrode (gate) 5. In the register, there is one complete cell for each photo diode. Right after the gate is closed, a new storage cycle begins, and the charges transferred to the register are read out serially. In this device, video signals can be output almost continuously, except for the brief interval for transfer of charges from under electrode 4 to register 6, and the photo diodes can store a charge during the entire cycle. It should be noted that this device has two analog registers: charges from even photo diodes are transferred to one register, and from odd ones to the other. The registers have independent charge detectors and output amplifiers. The registers have a four-phase system of control; therefore, temporary "deposit" of signals from the registers poses no problem [1].

The size of an elementary storage cell is 12 x 500 micrometers^2. Spectral range is 0.3 + 1.1 micrometers.

The range of recordable illuminations for these CCD's is determined by the storage time and lies within the range from

10^{-4} to 100 lk [lux]. CCD dynamic range is no less than 80 db. In the devices, there is the capability of electrical input into the registers of signal charge clusters. This permits performing summing of electrical and optical information in the CCD's themselves.

The capability of implementing certain functions for processing analog information in the CCD output unit permits, also without using digital processors, obtaining differential characteristics of the light distribution and thereby raises the accuracy of determining intensity maximums.

The rule CCD's discussed above with 50 and 500 cells and combined storage and transfer sections were used by us as output units in an acoustooptic spectrum analyzer, a diagram of which is shown in fig. 3. [AOM = acoustooptic modulator]

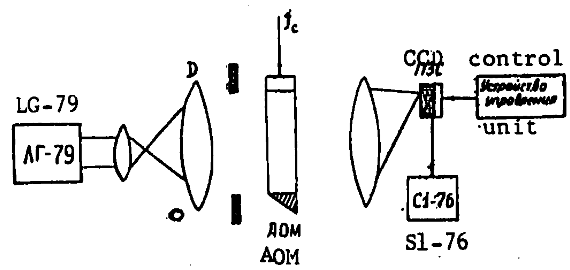

Fig. 3. Diagram of acoustooptic analyzer of the spectrum of radio signals

The spectrum analyzer with a 50-cell gage CCD was made on the basis of an acoustooptic modulator with an acoustic line of fused quartz with a central frequency F_0 = 130 MHz and had a frequency resolution $\Delta F \approx$ 100 kHz [4].

The gage CCD with 500 cells was used in a spectrum analyzer, made on the basis of an acoustooptic modulator with an acoustic line of lithium niobate and had a frequency resolution $\Delta F \approx$ 1 MHz and about 250 frequency channels.

Using CCD photo detectors expands considerably the capabilities of optical processing systems; it also facilitates alignment and adjustment of optical systems since the need for using complex scanning systems is eliminated.

These gage CCD photo detectors and their control systems are very compact and simple. They can be used not only in optical processing systems, but also in various other systems that require recording of light intensity distribution, for example, in astronomy at output of optic spectrographs, in geodesy in laser levels, etc.

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MEASURING GEOMETRIC DISTORTION IN TELEVISION BY OPTICAL FEEDBACK METHOD

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 218-222

[Article by G. A. Gavrilov and A. F. Malyy]

[Text] Annotation

Optical feedback permits visualizing and measuring raster distortions in a television system. The method is used in optico-television processors, but may be applied even more extensively in television.

Visual display and accurate measurement of the amount of raster distortion in television systems is a rather complex technical problem. Various methods have now been developed that basically meet the requirements of practice: test patterns and special signal generators, the method of moire patterns and a number of others [1]. The choice of a particular method for evaluating and measuring raster distortion depends on the specific nature of the problem to be solved and the technical level of the system used.

This paper pertains directly to measuring raster distortion in optical processors with television feedback [2, 3].

However, the feedback principle could be applied in other cases too, but to do this a sufficiently convincing substantiation of the expediency of using precisely this method is required.

The diagram of a processor with feedback is shown in fig. 1. The system output image, reproduced on a video monitor (VKU) screen, is the input image for the television transmitting camera (TK). The camera signal in negative polarity is combined with the input signal, and thus a negative feedback circuit is formed. The feedback makes the system stable and also very sensitive to raster distortions of the camera and video monitor.

The simplest input signal that provides clarity of the display of raster distortion of the device being measured and is convenient for measuring its value is the network field (SP) type signal.

Shown in fig. 2 are the waveforms of line signals in the system which illustrate the principle of measuring raster distortions. Assume that coming into system

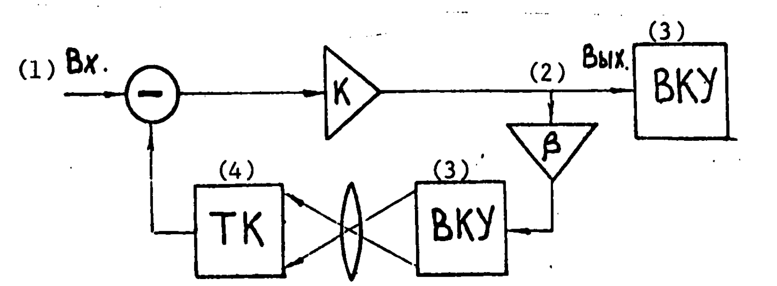

Fig. 1. Diagram of processor with feedback

Key:

1. input
2. output
3. video monitor
4. television transmitting camera

are pulses forming the image of a vertical grid (fig. 2a) on the video monitor screen. When there is no raster distortion in the system, the feedback signal (fig. 2b) coincides in time with the input signal, and an attenuated image of the grid (fig. 2c) is observed on the video monitor screen. When there is distortion in the device under study, the feedback signal appears shifted relative to the input signal (fig. 2d). Reproduced on the video monitor screen is the grid signal and the shifted image of the grid of opposite polarity (fig. 2e). It is evident that each successive passage of the signal through the feedback circuit results in new images of grids of alternating polarities (fig. 2f).

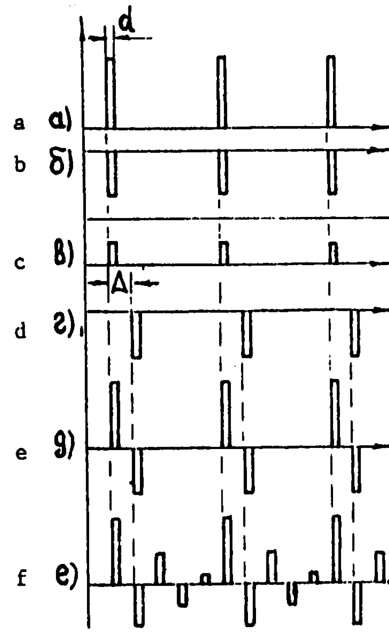

Fig. 2

Mathematically, the output signal for a line of the vertical grid in a system with feedback can be written in the form of

$$u(x) = u_0(x) K \sum_{n=0}^{N} (-1)^n (\beta K)^n \, rect(x - n\Delta), \quad \text{(I)}$$

where $u_0(x)$ is the input signal of the GSP [expansion unknown], K is the gain factor in the feed-forward circuit, β is the gain factor in the feedback loop, n is the number of passages of the signal in the OS [feedback] loop, and Δ is the value of raster distortions along the line

$$rect(x - n\Delta) = \begin{cases} 1, & |x - n\Delta| \leq \frac{d}{2} \\ 0, & \text{everywhere.} \end{cases} \quad (2)$$

It can be seen from expression (2) that the width of the vertical line of the grid (d) shapes the minimum value of raster distortions , which can be measured by the given method. In the extreme case, this quantity equals the system resolution element.

The gain β K is selected less than 1 so that the signals of the repeating grids are attentuated and become practically indistinguishable by the time the signal of the next vertical line of the input signal appears (fig. 2f).

Shown in fig. 3 is a sketch of the vertical lines on the video monitor screen and the type of geometric distortions, corresponding to it, in the system scanner.

The feedback method permits easy calculation of the quantity of raster distortions by the signal for the network field. It is convenient to take the raster center for the start of the readout of the value fo the raster distortions, for which it is necessary to achieve precise coincidence of the input image grid lines and the feedback signal at the center. In doing so, the shift in the feedback signal by the value of Δ in each of the squares of the network field will describe the absolute value of the raster distortion. The test signal of the network field contains p-cells for the raster height H, and the cell size b = H/p. The nonlinearity factor, by which it is customary to evaluate nonlinear distortions, is defined as [1]

$$K_H = \frac{b_i - b}{b} \quad \text{when} \quad b \ll H \ .$$

In the case in question, this value is written in the form of

$$K_H = \frac{\Delta}{b} = \frac{1}{n} \ ,$$

where n is the number of periods of repetition of the grids of the feedback signal in each square of the network field. The relative value of raster distortions of the raster is δ = 1/np. It is evident that determining the value of raster distortions does not require complex calculations.

a)

b б)

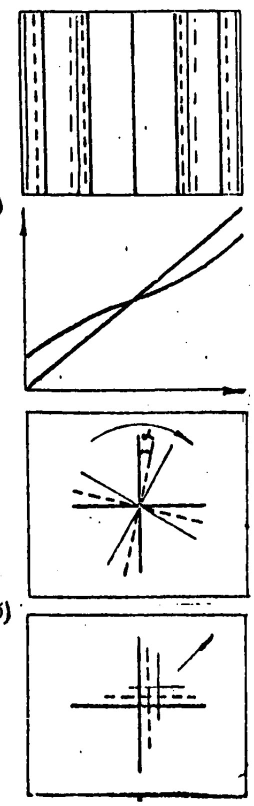

Fig. 3

In conclusion, it is necessary to say several words on the possibility of practical use of the feedback emthod for evaluating and measuring raster distortions. The method should not be considered universal. Use of it is expedient, for example, for tuning and on-line monitoring of the parameters of optical-television processors themselves with feedback. Shown in fig. 3b are sketches of the crosshairs on the video monitor screen when the camera is rotated relative to the video monitor by the angle α and when their axes are shifted and the scale disturbed.

It is evident that the feedback method does not permit separating raster distortions of the camera and video monitor. This can be done if one of these devices introduces negligible distortions of its own. Thus, to eliminate the effect of camera distortions, it is advisable to make use of solid-state PZS [CCD] type photo converters. These devices in accuracy of raster reproduction exceed by two orders of magnitude analog scanning devices. With such implementation, the method could be applied, for example, in measuring raster distortions and tuning video monitors with large screens.

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OPTICAL PROCESSING OF INFORMATION FROM ANTENNA SYSTEMS

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 337-340

[Article by N. A. Bukharin, I. A. Vodovatov, M. G. Vysotskiy, N. A. Yesepkina, V. Yu Petrun'kin and S. A. Rogov]

[Text] Annotation

Application of acoustooptic circuitry for processing signals from various antenna devices is discussed. Problems involving processing of signals from linear and two-dimensional antenna arrays and application of the principle of time multichanneling in the processing circuits are discussed. Data is given on a study of circuits for optical processing of information from ring antenna arrays.

A major application of coherent optics involves optical processing of signals from antenna systems. Used in the majority of cases are acoustooptical devices, i.e. devices in which acoustooptical modulators (AOM) are used for information input. Acoustooptical systems intended for processing signals from linear and planar antenna arrays were suggested by Lambert and his associates [1]. In processing the signals of a linear antenna array, the signals from elements of the array of the AR [antenna array] (fig. 1), after amplification and heterodyning, feed into the pseudo-converters of the AOM. The acoustic vibrations excited in the modulator channels form a dynamic diffraction grating, in which coherent light diffracts from the laser. Information on the spectrum of radiation and angular coordinate of the signal source is contained in the focal plane of the integrating lens L_1, in the first orders of diffraction.

In the case of a two-dimensional antenna array, circuits with time multichanneling can be applied. In these circuits, signals from the line of antenna elements feed into each of the AOM channels. They receive time delays in advance since the acoustic vibrations corresponding to the signals from the various line elements are spatially separated. In the focal plane in the first diffraction order, we obtain the spot, the position of which characterizes two angular coordinates of the signal source.

The principle of time multichanneling can also be used in processing complex signals. Used in this case are different versions of circuits, including circuits with spatial filtration.

Key:
1. AR [antenna array]
2. U [amplifier]
3. G [heterodyne]
4. from the laser
5. AOM [acoustooptical modulator]
6. L_i [integrating lens]

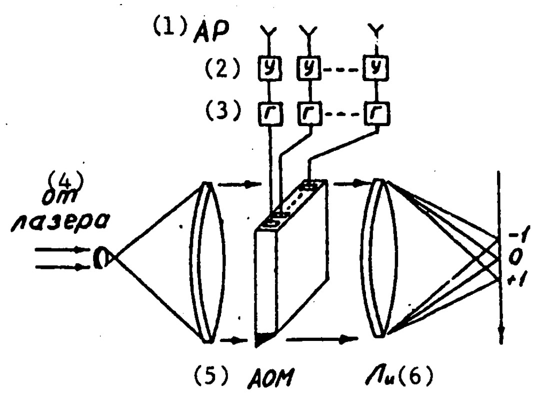

Fig. 1.

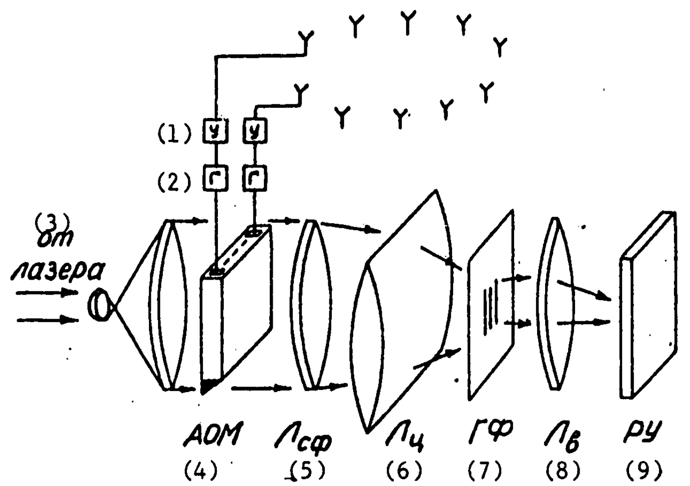

Fig. 2.

Key:
1. U [amplifier]
2. G [heterodyne]
3. from the laser
4. AOM [acoustooptical modulator]
5. L_{sf} [spherical lens]
6. L_{ts} [cylindrical lens]
7. GF [holographic filter]
8. L_v [spherical lens]
9. RU [recording unit]

Optical methods are very promising in processing signals from ring antenna arrays [2]. The circuits used in these cases differ from those used in processing signals from linear and planar arrays: Filtration matching is used to match the phases of the signals coming from elements in a ring array. Set in the plane of the spatial frequencies is a holographic filter that is a recording of the spatial-frequency spectrum of the transmissivity of the reference transparency.

Generated in the system output plane is the distribution of light that is proportional to the cross-correlation function of the transmissivity of the reference transparency and the AOM transmissivity when signals from the antenna array are fed to it. The distribution thus obtained corresponds to the radiation pattern of the ring antenna and permits determining the azimuth of the signal source.

As research [3] has shown, the capabilities of this system can be substantially expanded by using certain measurements of the optical circuit. Thus, application of an astigmatic circuit (fig. 2) permits in addition to determining the signal source azimuth studying the spectral composition of the signal. In this circuit, a pair of lenses, consisting of a spherical lens L_{sf} and a cylindrical lens L_{ts}, effect a Fourier transformation along the horizontal coordinate and generate an image along the vertical coordinate. After filtration by using the holographic filter GF, the spherical lens L_v performs an inverse Fourier transformation. As a result of this, at system output in the plane of the recording unit RU, a light distribution is generated that along the horizontal characterizes the signal source azimuth, and along the vertical, the signal spectrum.

Among other applications of coherent optical methods in antenna technology, we should mention the study of characteristics and processing of signals of antenna arrays with random arrangement of radiating elements. Antennas of this type [4] are used to develop systems with narrow radiation patterns with a reduction in the total number of radiators. Determining the characteristics of such antennas, in particular, of two-dimensional radiation patterns is a rather complex problem requiring large inputs of computer time. The method of optical simulation of the radiation patterns simplifies considerably solving it.

Acoustooptical circuits similar to those applied in the case of entirely filled arrays can be used to process signals from antenna arrays with random arrangement of the elements.

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ANALYSIS OF CONDITIONS OF GENERATION AND OPTICAL PROCESSING OF INFORMATION AT RADAR INSTALLATIONS WITH SYNTHETIC APERTURE

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[Article by Yu. S. Zinov'yev and A. Ya. Pasmurov]

[Text] Annotation

Discussed in this work is a new approach to describing radar systems with synthetic aperture based on the principle of holography.

It is known [1, 2] that at RLS [radar installations] with synthetic aperture (RSA), resolution by one coordinate (azimuth) is achieved by holographic processing of a recorded signal. Till now, application of the holographic approach to analyze the process of obtaining images at RSA has been limited to consideration of the optical processor. In practice, there has been no mathematical substantiation of the point of view that is the RSA as a whole as a holographic system. In this work, we have analyzed the conditions for generating and optically processing RSA signals from the unified positions of holography.

Let us consider an RSA moving at velocity v along the x' axis. The installation records serially in time a picture of the diffraction of the probing signal on objects of observation. The received and reference signals ("artificial" reference wave) interfere in a coherent detector. As a result, a hologram of the multiplying type [3] is generated which is recorded by modulation of the intensity of the luminescence of an ELT [cathode-ray tube = CRT] on photographic film, which is moving relative to the CRT screen at velocity v . Assume all objects are located at the same range R_0 from the x' axis (in the process, the radiated signal can be considered continuous). If the scattering properties of a linearly distributed object are described by the function $F(x_0)$, and its dimensions by $x_{0\,max} \ll R_0$, we will obtain an approximation of the fresnel [4] for the diffraction field along the x' axis (with regard to propagation of the signal to the object and back):

$$U_0(x') = C\frac{e^{iK_1R_0}}{\sqrt{\lambda_1 R_0}}\int_{-\infty}^{\infty} F(x_0)\, e^{iK_1\frac{(x_0-x')^2}{R_0}}\, dx_0 , \qquad (I)$$

where $K_1 = 2\pi/\lambda_1$ is the wave number and C is some constant.

Reference wave amplitude equals $U_r(x') = A_r e^{i\varphi_r}$. Conventionally $\varphi_r = K_1 \sin\theta x'$ (θ is the angle of "incidence" of planar wave on the hologram), which provides for introduction of the carrier frequency $\omega_x = K_1 \sin\theta$.
The equation of the hologram obtained is

$$h(x') = Re(U_r^*(x') U_0(x')) \text{ or } h(x') = Im(U_r^*(x') U_0(x')). \quad (2)$$

With regard to (1), it is clear that in the general case at the RSA, unidimensional Fresnel holograms are generated. The following situations are also possible. In the case when $R_0 \gg K_1 x_0^2{}_{max}$,

instead of (1), we obtain the approximation of Fraunhofer:

$$U_0(x') = C \frac{e^{iK_1 R_0}}{\sqrt{\lambda_1 R_0}} e^{iK_1 x'^2} \int_{-\infty}^{\infty} F(x_0) e^{iK_1 \frac{2x' x_0}{R_0}} dx_0, \quad (3)$$

as a result of which a Fraunhofer hologram is generated.

In the case when $R_0 \gg K_1 L_s^2/8$ (L_s = vT is the length of the synthetic aperture and T is the time of recording of the hologram), the term $\exp(iK_1 x'^2/R_0)$ can be omitted in (3). In doing so, a Fourier hologram is formed, the condition for obtaining of which let us notate in the form of

$$L_s \leq 2\sqrt{\lambda_1 R_0/\pi}. \quad (4)$$

If the object is a point $(F(x_0) \sim \delta(x' - x_0))$, then the conditions of the Fraunhofer diffraction are met. By using the filtering property of the δ-function, let us derive from (3) the following hologram equation (without regard to the constant phase terms):

$$h(x') = A_r A_0 \cos(\omega_x x' - K_1 \frac{x'^2}{R_0} + 2K_1 \frac{x' x_0}{R_0}, \quad (5)$$

where A_0 is the amplitude of the wave scattered by the object at the point of reception.

Also, if (4) is met, then it follows from (5) that

$$h(x') = A_r A_0 \cos(\omega_x x' + 2K_1 \frac{x' x_0}{R_0}). \quad (6)$$

Thus, for a point object, a Fraunhofer or Fourier hologram is generated at the RSA. In the first case, the hologram takes the form of a one-dimensional zonal Fresnel array, in accordance with (5), and in the second, a sinusoidal array in accordance with (6). In the process of photographic recording, scaling of the holograms is effected with replacement of the coordinate x' by x, where x = x'/n_x, and $n_x = v/v_n$.

In the process, added to (5) and (6) is the constant term h_0 ("shift"), needed for photographic recording of the bipolar function h(x').

At the stage of regeneration of the image, exposing the photo transparency by a planar wave with wave number K_2, let us derive a diffraction field, the distribution of which at distance ρ from the hologram is described by the Huygens-Fresnel integral:

$$V(\eta) = \frac{e^{i(K_2\rho - \pi/4)}}{\sqrt{\lambda_2 \rho}} \int_{-v_n T/2}^{v_n T/2} h(x) e^{i\frac{K_2}{2\rho}(x-\eta)^2} dx. \quad (7)$$

Substituting (5) in (7), let us derive the following functions that describe images of a point object

$$\left.\begin{matrix} V_1(\eta) \\ V_2(\eta) \end{matrix}\right\} = C \int_{-v_n T/2}^{v_n T/2} e^{i\left(\frac{K_2}{2\rho} \pm \frac{K_1 n_x^2}{R_0}\right)x^2} e^{-i\left[\frac{K_2\eta}{\rho} \pm \left(\omega_x n_x + \frac{2K_1 n_x x_0}{R_0}\right)\right]x} dx. \quad (8)$$

Let us find the longitudinal position of the images from the condition of equality to zero of the index of the first exponent in (8); hence it follows that

$$\rho = \pm \lambda_1 R_0 / 2\lambda_2 n_x^2. \quad (9)$$

Integrating (8) under condition (9), let us derive that the images are described by a function of the type sin ν/ν, where

$$\nu = \left[\omega_x n_x + \frac{2K_1 n_x^2}{R_0}\left(\frac{x_0}{n_x} - \eta\right)\right]\frac{v_n T}{2}. \quad (10)$$

The position of the image along the x axis is determined, evidently, by the relationship

$$\eta = x_0/n_x + \omega_x R_0 / 2K_1 n_x. \quad (11)$$

The first term in (11) corresponds to the coordinate of the object, and the second is shaped by the carrier frequency. Images of two points having a common coordinate x_0, but different values of range R_1 and R_2, are characterized by different coordinates η_1 and η_2, i.e. use of the carrier frequency leads to geometric distortions of the image of the band of view.

By Rayleigh's criterion, two points will be separated if the main maximum of one of the functions of the type sin ν/ν coincides with the first zero of the other. Hence follows the evaluation of the resolution:

$$\Delta x' = x_1' - x_2' = \pi R_0 / K_1 L_s.$$

In RSA theory, the case of using the Fraunhofer hologram has received the name of "focused aperture." By focusing should be understood compensation for quadratic advance of phase in (5), effected in the processing stage by using conversion (7). The case of "unfocused aperture" corresponds to the equation for the Fourier hologram (6). Accordingly, in the processing stage, the Fourier transform of the hologram function is used; hence it follows that the images of points are also described by functions of the type $\sin \nu/\nu$, where

$$\nu = \left[\frac{K_1}{\rho}\eta \pm \left(\omega_x n_x + \frac{2K_1}{R_0} n_x x_0\right)\right]\frac{v_a T}{2}.$$

The value of ρ is the focal length of the Fourier lens. The position of the image is determined by the equation

$$\eta = \pm \frac{\rho}{K_1}\left(\omega_x n_x + \frac{2K_1}{R_0} n_x x_0\right).$$

The image of the entire band of view will also be distorted as a consequence of the dependence of η on the range R_0. The maximum attainable resolution in an RSA with unfocused aperture is by Rayleigh's criterion with regard to (4) the value of

$$\Delta x' = \sqrt{\pi\lambda_1 R_0}/4 \approx 0.44\sqrt{\lambda_1 R_0}.$$

Let us note that holograms are recorded on photographic film continuously in the process of the flight of the RSA carrier. Therefore, the focused or unfocused mode is specified at the stage of obtaining the image by selecting the dimensions of the diaphragm, which determines the value of L_s/n_x, and by the appropriate design for the optical processing circuit.

Thus, the holographic approach permits conceiving of an RSA and optical processor as a unit. In doing so, the essence of the physical processes occurring in recording and optical processing of RSA signals is disclosed most fully.

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ON-LINE OPTICAL PROCESSING OF INFORMATION IN RADIO-HOLOGRAPHIC SYSTEMS

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 346-350

[Article by S. V. Morozov]

[Text] Annotation

Discussed is an optico-electronic Fourier-processor with on-line output of processed information in sections by the method of heterodyne scanning, intended for realization of the operation of a two-dimensional Fourier transform in radio-holographic systems.

Results are given for an experimental test of device operating capability.

In solving a number of practical problems, information on objects under investigation is obtained by holographing them in the radio range. The need for obtaining information by a similar method occurs in systems for microwave imaging and investigation of the scattering properties of bodies. In this case, when processing the derived information, it is necessary to find the initial distribution of the radio field according to a specified amplitude-phase distribution which is recorded by the holographic method.

Information processing in the systems in question with the validity of the Fresnel approximation can be reduced to execution of a Fourier transform from some two-dimensional complex function. This operation can be performed by both digital and analog methods.

Existing digital devices for information processing in a number of cases do not have acceptable speed.

Analog optical devices for information processing can perform the Fourier transform within a very short time interval. They are also considerably simpler, cheaper and more compact than digital computers.

The potential speed of analog optical devices for information processing, Fourier processors, can be realized with application of on-line devices for information input (this is achieved by application of controllable transparencies) and with provision for on-line output of information.

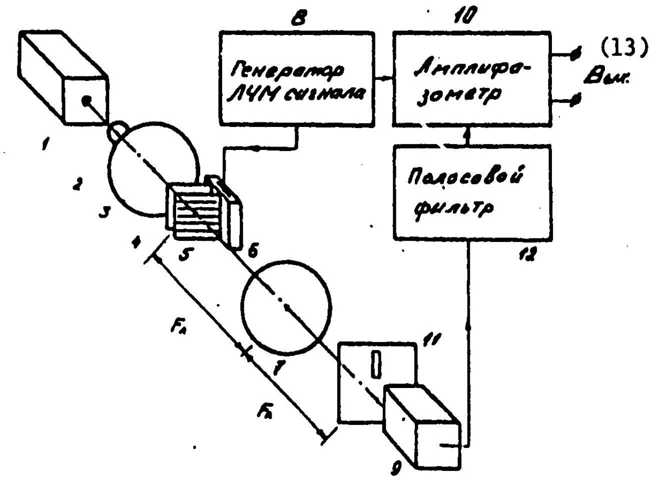

Fig. 1.

Key:
8. generator of linear-frequency-modulated signal
10. amplitude-phase-meter
12. band-pass filter
13. outputs

Very promising from the viewpoint of the capability of on-line output of information is the method of heterodyne scanning [1].

Based on this method, a device was developed (fig. 1) [2] that effects an on-line Fourier transform of the two-dimensional amplitude-phase distribution and output of the results obtained in the form of a set of sections of the amplitude and phase spectra of the Fourier of the distribution being studied.

The optical-electronic Fourier-processor operates as follows.

A collimated light beam illuminates transparency 4 with recording of the distribution under investigation. Diffraction grating 5, with the sinusoidal distribution recorded on it, provides for spatial modulation of the light distribution, corresponding to the function being studied, and thereby shifts the Fourier spectrum, generated in the focal plane of the integrating lens, into the region of the first diffraction order of light, diffracted by an ultrasonic wave in an ultrasonic light modulator (UZMS)-6. The UZMS is set in the same plane as the transparency on which the distribution being studied is recorded.

When a signal with linear-frequency modulation (LChM) is fed to the electrical input of the UZMS-6, scanning diffraction beams emerge on its shadow side. One of these beams, namely the first diffraction order, strikes the photo sensitive surface of a photo detector. Thus, two light beams interfere on the surface of the photo detector: the Fourier spectrum of the distribution under investigation and the scanning diffraction order from the UZMS.

The signal at the output of the photo detector, carrying information on the amplitude and phase of the distribution under investigation, is isolated by band-pass filter 12; the frequency shift of the light in one of the interfering beams, required during heterodyning, is achieved through diffraction of the light by a travelling ultrasonic wave.

The slit diaphragm 11, set in front of the photo detector, is designed to destroy extraneous illuminations and generate the specified section of the Fourier spectrum of the distribution under investigation. The output signal is generated at a radio frequency and is isolated by band-pass filter 12. One section of the Fourier spectrum is recorded in the device in question. Any other section can be obtained when the transparency is rotated about its axis.

To perform experimental research of optico-electronic Fourier-processors, an installation was assembled on the base of the OSK-2 optical system. An OKG-LG-38 was used as the source of coherent light. The size of the transparency and diffraction grating was 10 x 10 mm^2. The UZMS had a central frequency of 30 MHz with a bandwidth at the level of 0.7-6 mHz. The acoustic line material was distilled water.

The experiments performed confirmed the correctness of the basic theoretical propositions. A section of the two-dimensional Fourier spectrum of the distribution under investigation was generated at the output of the device within 1/50 sec. The time of output of information could be varied by varying the parameters of the LChM signal.

Dynamic range of output signals was 30 db. The value of the dynamic range obtained in the experiment is lower than its maximum value, which is due to noise during output of information (shot noise of the photo detector - FEU [photoelectric amplifier]), as a consequence of inefficient use of the energy from the light source. The maximum value of the dynamic range of the output signals is restricted due to noise from the optical system, noise from the light source and noise from the information input device.

The dynamic range of the output signals is narrowed further as a consequence of spatial side lobes of the diffraction spectrum of the zero order striking the region of location of the signal.

Thus, for a quadratic cophasal aperture with a dimension of 2ax2B, the dynamic range, shaped by just the side lobes of the zero order, is

$$D = \frac{4b^2 \eta_{T1}}{(\eta_{T0} 4b^2 + \eta_{M0} d^2 + 4bd\sqrt{\eta_{T0}\eta_{M0}}\,(\frac{\sin 2\pi\Omega_0 a}{2\pi\Omega_0 a})^2},$$

where η_{T0}, η_{T1} is the diffraction efficiency of the transparency for the zero and first order of diffraction;

η_{M0} is the diffraction efficiency of the UZMS for the zero order of diffraction; and

Ω is the spatial frequency of the diffraction grating.

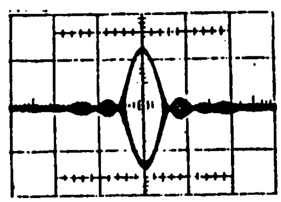

Fig. 2.

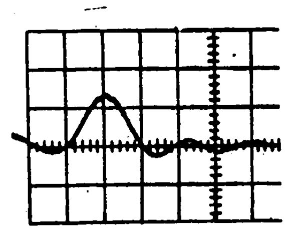

Fig. 3.

Shown above are the results of an experimental test of the device operating capability. Fig. 2 shows the section of the amplitude Fourier spectrum of the distribution under investigation--round cophasal aperture. Fig. 3 shows the section of the amplitude-phase Fourier spectrum of the distribution under investigation--square cophasal aperture.

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OPTICAL CALCULATION OF SIGNAL AMBIGUITY FUNCTION

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 351-357

[Article by Ye. K. Shmarev]

[Text] Annotation

A survey and classification are made of optical methods and systems for computing a signal ambiguity function.

The ambiguity function (FN) plays a fundamental role in radar and sonar. In a narrow-band approximation of consideration of the Doppler effect for the signal $s(t) = u(t) \exp (j\, 2\pi w_o t)$, it is defined as [1]

$$\chi(\tau, w) = \int u(t)\, u^*(t-\tau) \exp(-j\, 2\pi w t)\, dt, \qquad (1)$$

where $u(t)$ is the complex modulating function of the signal, w_o is the signal carrier frequency, τ is the relative delay and w is the Doppler shift of the frequency. In the wide-band case, the ambiguity function can be notated in the form of [2]

$$\chi(\tau, \beta) = \sqrt{\beta} \int s(t)\, s^*[\beta(t-\tau)]\, dt, \qquad (2)$$

where $\beta = \frac{c-v}{c+v}$ is the Doppler parameter, v is the range rate of target movement and c is the velocity of propagation of waves in the medium.

Computation and display of the body of the ambiguity function has two major aspects for detection and ranging systems. On the one hand, it permits judging the information properties of the signal being emitted, and on the other, it is a unique two-dimensional indicator of the detection and ranging situation in the "range-speed" coordinates which operates under the conditions of optimal reception.

All the optical systems that exist up to now for computing the ambiguity function can be conventionally divided into three classes. The first is based on the spectral representation of the narrow-band ambiguity function as Fourier-images from the product of the functions $u(t)$ and $u^*(t-\tau)$. This approach is the simplest to implement, but its applicability is limited to the narrow-band approximation.

The second class uses the correlation method for computing the ambiguity function. With that, in the narrow-band approximation, the ambiguity function (1) is represented as

$$\chi(\tau, \omega) = [u(t)\exp(-j2\pi\omega t)] * [u(t)] \qquad (3)$$

and in the wide-band case as

$$\chi(\tau, \beta) = s(t) * s(\beta t), \qquad (4)$$

where the * defines the correlation operation. Systems in the third class use nonlinear algorithms to compute functionals that have properties close to those of the classical ambiguity function. In such systems, the optical Mellin transform can be used in particular.

Let us discuss the most typical systems for optical computation of the ambiguity function.

Spectral Method. An optical system for performing a unidimensional Fourier transform is built traditionally by using cylindrical and spherical lenses. The basic problem in computing the ambiguity function comes down to representing the signal to be studied u(t) at the output of the optical system in the form of a distribution of a field of complex amplitude u*(x-y). Thus, in [3], the signal is transformed into the needed form by creating discrete time delays in the elctronic path with successive ordering of the delayed signals on the y coordinate with recording on a transparency. It is more convenient to make use of a turn of the transparencies with recording of the signal in the input plane of the optical scheme. This principle was the basis for the scheme implemented by Said and Cooper [4], fig. 1. The transmission of the transparency with recording of the signal u(x), turned at angle θ to the axes of the coordinates, can be notated as $u(x\cos\theta + y\sin\theta)$. The respective transmission of two transparencies, turned at angles of 45° and -45°, will be

$$u\left[\frac{x+y}{\sqrt{2}}\right] \text{ and } u\left[\frac{x-y}{\sqrt{2}}\right].$$

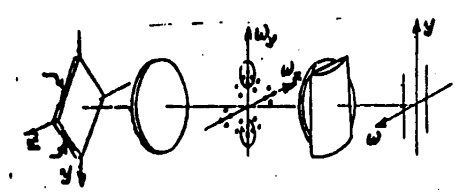

Fig. 1.

The field of complex amplitude at the output of the optical system is described by the function

$$V(y, \omega) = \int_{-\infty}^{\infty} u\left(\frac{x+y}{\sqrt{2}}\right) u\left(\frac{x-y}{\sqrt{2}}\right) \exp(-j2\pi\omega x)\, dx \qquad (5)$$

or after substitution of the variable $x' = (x+y)/\sqrt{2}$

$$V(y, \omega) = \sqrt{2}\,\chi(\sqrt{2}y, \sqrt{2}\omega)\exp(j2\pi\omega y), \qquad (6)$$

which corresponds to the ambuiguity function with a precision to the phase multiplier. Used in the input plane in the scheme shown in fig. 1 was an acoustic-optical modulator in water; the signal was input into it from two mutually perpendicular directions. An intermediate frequency plane P_2 was used for filtration of the spectral components corresponding to the the modulating function. Similar scheme solutions were studied in [5, 6]. In [7], this scheme was implemented by using a PVMS [spatial-time light modulator] of the "phototitus" type. In [3], the possibility of computing the ambiguity function from complex functions was considered by using coding of the complex signal in the electronic path. In [6], an optical scheme was discussed with one input transparency, through which the light passes twice, and at output the ambiguity function is reflected in a form similar to expression (6). An astigmatic system was suggested in [8] that permits optical transformation of an image into an oblique-angled system of coordinates and thereby provides for representation of the signal u(x) in the form u(x-y). The system reflects the ambiguity function without distorting phase multipliers and permits varying the scale on the correlation axis.

Correlation Method. This method of computing the ambiguity function is more general, since it can be generalized for the case of the wide-band ambiguity function. Various modifications of correlators can be used for the optical implementation: 1) Van der Lyugt, 2) with generalized hologram, 3) with movable transparency. Used in [9] for computation of the narrow-band ambiguity function was the scheme of the multichannel Van der Lyugt correlator with filters recordable on a matrix of photo plastic. Discrete values of the phase factor $\exp(-j2\pi w_n t)$ in expression (3) were specified by means of a turn of the plane-parallel plate through which a light beam was passed in the stage of recording the next filter, matched with the specific Doppler frequency w_n.

For a similar purpose, it was proposed in a patent [10] to make use of a special mutlichannel cylindrical lens, the focus and position of the center of which vary along the y coordinate in a scheme of a holographic correlator. Another version of a correlation scheme with the use of a combination of two-dimensional and one-dimensional Fourier stages in a scheme with a generalized hologram was described in [9].

When the signal to be analyzed takes the form of a series of pulses (from a pulse-Doppler radar, for instance), a holographic scheme suggested in patent [11] can be used (see fig. 2).

In it, correlation on the time axis x is effected by using filtration by a one-dimensional holographic filter placed in plane P_1. Lens L_3 forms the correlation function on axis x_2 and the "fine" spectral distribution on axis y_2. Formation of the "fine" structure of the spectrum on the axis y_2 is effected in accordance with the method of spectral analysis according to Thomas [12].

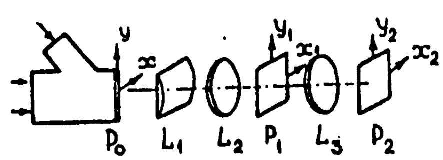

Fig. 2.

An interesting approach based on representation of the ambiguity function as a bilinear transformation is given in [13]; also given there is an original non-holographic correlation scheme for obtaining sections of the narrow-band ambiguity function.

Results of experimental research on systems for calculating the ambiguity function were published in [14].

Mellinovskaya Ambiguity Function. The authors of [15, 16] suggested using the Mellinovskaya correlation invariant to the time scale for Doppler processing of signals. To realize this processing, a logarithmic sweep ($x = \ln t$) is used at the input of the optical correlator in recording the signal. In effecting the correlation between the signal s(t) and s(β t), the field of complex amplitude at system output is described by the function

$$u(x_0) = s(x) * s(x) \otimes \delta(x - \ln\beta). \qquad (7)$$

Shifting the correlation peak permits determining the value of the Doppler parameter β, however, the algorithm for processing loses invariance to the time delay. Therefore, the second spatial coordinate of the correlator must be used to realize the exhaustive search by delays.

Experiments performed by digital simulation of the calculation of the Mellinovskaya ambiguity function have shown that a numder of substantial shortcomings are inherent to it. Thus, for example, broadening of the correlation peak occurs compared to the classical linear ambiguity function (for the 13-element Barker code, the correlation peak is broadened threefold), which leads to deterioration of system resolution and noise immunity is also reduced. According to the authors of [15], these shortcomings can be eliminated if two coordinate transformations are used, one for the signal being emitted and a second one for that detected.

The functional scheme for computing the Mellinovskaya ambiguity function with dual transformation (MFNDP) is illustrated in fig. 3.

The idea of this method is based on the fact that the optimal representation for the radiated coded signal will be that which will yield the initial linear code after transformation of the signal upon reception. Since after reception, the signal is subjected to exponential transformation of the coordinates (logarithmic sweep), it must be transformed in the logarithmic scale (exponential sweep) before radiation.

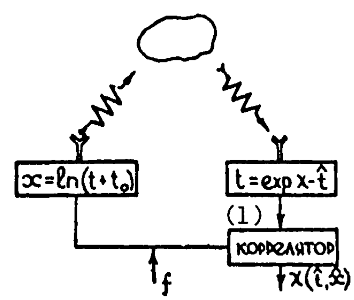

Fig. 3.

Key:
1. correlator

The system can be built by using optical schemes for transformation of coordinates (since transformation must be effected in parallel in real time) [17, 18] and a correlator that contains a holographic filter and a movable input transparency with recording of the transformed received signal.

Theoretical analysis has shown that the MFNDP permits separating signals by the axis of range and Doppler; however, reading the Doppler shift is determined by the correlation axis, and reading the range by the axis of the frequencies. Also, these readings are not independent. It should be noted that a system with the MFNDP permits within certain limits varying by parameters of the resolution for the range and Doppler, which is not possible in systems with a linear ambiguity function.

Given in [18] are the results of digital simulation of the algorithm for computing the MFNDP for the most typical radar signals. The authors promised to publish the results of optical simulation of this algorithm in the near future.

Conclusion. It can be seen from this survey that considerable interest in optical methods of correlation-Doppler processing of signals has emerged in recent years.

The spectral method of computing the ambiguity function is the simplest; it should be used for radar systems to which narrow-band representation of signals is applicable. Correlation systems are promising for processing wide-band signals, for example, in sonar.

Further research on the method of nonlinear optical processing, in particular, the MFNDP, will permit defining the class of problems for which application of the corresponding complex systems will be warranted.

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OPTICAL CALCULATION OF SIGNAL AMBIGUITY FUNCTION WITH VARIABLE SCALE ON AXIS OF DELAYS

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 358-360

[Article by S. V. Levyy and Ye. K. Shmarev]

[Text] Annotation

An optical system is suggested for calculating a signal ambiguity function. The capability of controlling the scale on the axis of delays is shown. Experimental results are given for calculation of the ambiguity function for sampled signals.

An optical system for calculating the FN [ambiguity function] of signals in a narrow-band approximation was described in [1]. In this system, a signal was set in two spatial modulators along the orthogonal spatial axes. The shortcomings in this system include the rigid requirements on the quadratic geometry of the input modulator which precludes the possibility of implementation of a multichannel system, and the presence in the output field of complex amplitude of distortion phase factor fo the type $\exp j\,2\pi\,wy$. These shortcomings can be eliminated if one of the input signals u(t) is represented in the spatial modulator in the form u(x+y), where x, y are the spatial coordinates in the input plane. Converting the function u(x) into u(x+y) can be considered a shift to an oblique-angled system of coordinates and can be represented in the form of

$$u(x+y) = F^{-1}_{w_x}\left[F_x[u(x)]\exp j\,2\pi w_x y\right], \qquad (I)$$

where F_x and $F^{-1}_{w_x}$ are, respectively, the operators of a direct and inverse Fourier transform.

Thus, according to [1], the necessary signal transformation can be made optically based on two one-dimensional Fourier stages and a phase transparency that is a wedge in the plane w_x, y_c, which increases linearly along one spatial coordinate at an angle. Let us consider the possibility of implementing this transparency based on the two cylindrical lenses in fig. 1. The transmission of the cylindrical lens turned at angle φ to the x axis can be notated in the form of [2]

$$\tau_\Lambda(x,y) = \exp -j\frac{K}{2f_\Lambda}x'^2 = \exp -j\frac{K}{2f_\Lambda}(x\cos\varphi - y\sin\varphi)^2 \quad (2)$$

where $K = 2\pi/\lambda$, f_Λ is the focal distance of the lens.

Accordingly, the transmission of the two cylindrical lenses turned at angles φ_1 and φ_2 will be

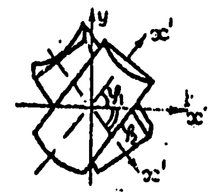

Fig. 1.

$$\tau_{\Lambda_1}\tau_{\Lambda_2} = \exp -j\frac{K}{2}\Big[\frac{1}{f_1}(x^2\cos^2\varphi_1 + y^2\sin^2\varphi_1) + \frac{1}{f_2}(x^2\cos^2\varphi_2 + y^2\sin^2\varphi_2) - \frac{2}{f_1}xy\cos\varphi_1\sin\varphi_1 - \frac{2}{f_2}xy\cos\varphi_2\sin\varphi_2\Big]. \quad (3)$$

Considering $f_1 = -f_2 = f_\Lambda$ and $\varphi_1 = -\varphi_2 = \varphi$, then

$$\tau(x,y) = \exp -j\frac{2K}{f_\Lambda}xy\sin 2\varphi \quad (4)$$

Thus, the transmission function of this lens system corresponds to the required transmission function for the phase transparency.

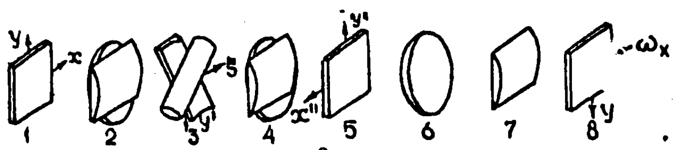

Fig. 2.

Fig. 2 illustrates a complete optical scheme for computing the ambiguity function. In planes 1 and 5, the input signal appears along the x coordinate. Optical system 2-3-4 effects transformation of the image from plane 1 into an oblique-angled system of coordinates in plane 5 in accordance with the algorithm (1). The field of complex amplitude in plane 5 behind the phase transparency can be notated as

$$u_5(\xi,y') = \Big[\exp -j\frac{2K}{f_\Lambda}\xi y'\sin 2\varphi\Big]\int_{-\infty}^{\infty} u_1(x,y')\exp -j\frac{K}{f_0}\xi x\,dx \quad (5)$$

After effecting the inverse Fourier transform by ξ and reflection by y, the field in plane 5 will be

$$u_5(x'',y'') = u(x',y') \overset{x'}{\otimes} \delta\Big(\frac{K}{f_0}x' - y'\sin 2\varphi\Big) = u\Big(x'' - \frac{f_0}{f_\Lambda}y''\sin 2\varphi, y''\Big) \quad (6)$$

where $\otimes$ denotes the convolution operator, δ is the delta function of Dirac, and f_0 is the focal distance of the astigamtic pairs 2 and 4 on the x axis. The last expression corresponds to the representation of the image of u(x, y) in the oblique-angled system of coordinates with the angle between the axes x'' и y'' — α:

$$\operatorname{tg}\alpha = \frac{f_\Lambda}{f_0\sin 2\varphi} \quad (7)$$

If transparencies with transmission u(x) are placed in planes 1 and 5, then the field of complex amplitude of the light in plane 8 can be represented in the form:

$$\chi(y, w) = \int u(x)\, u\left(x - \frac{f_2}{f_1} y \sin 2\varphi\right) \exp -j 2\pi w_x x \, dx \qquad (8)$$

(here the scale factors that depend on the parameters of the astigmatic pair 6 and 7 are omitted).

Thus, generated at system output is a two-dimensional ambiguity function of the signal being analyzed with distorting phase factors and at a scale on the axis of delays, determined by the parameter φ .

Fig. 3a illustrates an example of transformation of coordinates in an image with three values of the parameter φ , and fig. 3b [figures not reproduced] shows the result of computation of the mutual ambiguity function of sampled signals for four values of the scale on the axis of delays.

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HIGH-FREQUENCY ACOUSTO-OPTIC ORTHOGONAL FILTERS

Leningrad PRIMENENIYE METODOV OPTICHESKOY OBRABOTKI INFORMATSII I GOLOGRAFII in Russian 1980 (signed to press 16 Dec 80) pp 361-365

[Article by V. N. Ushakov]

[Text] Annotation

Proposed in this work is the implementation of high-frequency orthogonal filters based on an acousto-optic correlator, which is in essence a line electrical filter, the pulse response of which is defined by the structure of the reference transparency.

The factors that restrict the capability of synthesis of such filters by methods of acousto-optics are pointed out.

It is known that high-frequency (VCh) orthogonal filters can be efficiently used in solving a number of radio engineering problems. In particular, they are promising in the synthesis of high-frequency band-pass filters or in correlation analysis of high-frequency random processes [1]. However, if traditional radio engineering methods are used as the basis for circuit solutions for high-frequency orthogonal filters, then implementation of the required frequency responses of electronic filters with a given accuracy is a complex engineering problem, and in a number of cases it is fundamentally impossible.

The broad functional capabilities of optical information processing systems now permit development of devices for various purposes based on them. For example, described in [2] is an orthogonal coherent optical fiiter, implemented on the basis of a thermoplastic record, which determines the relative complexity of its practical execution. Also, the device functions only in quasi-real time.

Suggested in this work is implementation of high-frequency orthogonal filters on a base of a known acousto-optical (AO) correlator [3], which is essentially a line electrical filter, the pulse response of which is defined by the structure of the reference transparency. Such a filter has certain advantages compared to radio engineering implementations. In particular, synthesis of a filter with a given pulse response comes down to manufacturing a reference transparency with a suitable principle for varying its transmittance, and in a number of cases, that which can not be made by radio engineering methods is implemented in the AO correlator. In the process, the relative simplicity and universality of the device that is attained when variation in the nature of the pulse response entails just replacement of the reference transparency makes the AO a very attractive alternative.

Let us consider an AO implementation of a quasi-orthogonal high-frequency basis of the form $\{\Psi_i(t)\cos w_0 t; \Psi_i(t)\sin w_0 t\}$, where $\{\Psi_i(t)\}$ is a known system of low-frequency orthogonal functions (t = 1, 2, 3, ...) and w_0 is the angular frequency of the high-frequency process subject to orthogonal decomposition. A structural diagram of the simplest AO correlator is shown in fig. 1.

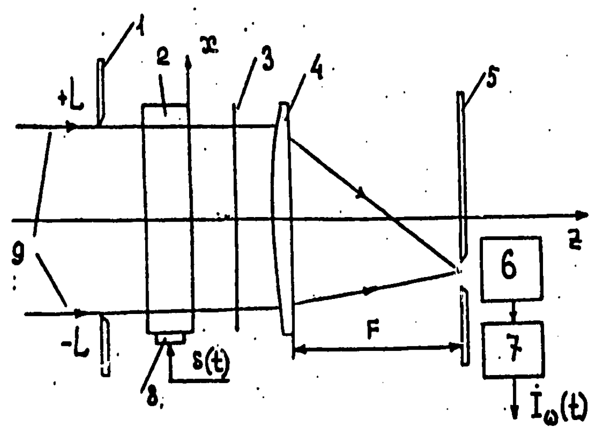

Fig. 1.

It is composed of an ultrasonic light modulator (UMS), which includes acoustic line 2 with piezo transducer 8, reference transparency 3, cylindrical transforming lens 4, diaphragms 1 and 5, which restricts the input collimated beam 9 and cuts out one of the first orders of the diffraction pattern at focal distance F, respectively. Radio signal S(t) is fed to the UMS input and current, the complex envelope of which is designated $\dot{I}w(t)$, is removed from the device, photo detector 6/band-pass amplifer 7.

Since in the expression $\Psi_i(t)^{\cos}_{\sin} w_0 t$, the function $\Psi_i(t)$ in the general case is alternating, then let us write the relationship for the pulse response of the i-th orthogonal high-frequency filter from the system $\left\{\Psi_i(t)^{\cos}_{\sin} w_0 t\right\}$ in such a way that the amplitude multiplier describes the AM principle, and let us attribute the change of its sign to the phase function $\theta(t)$, i.e.

$$h_i(t) = |\Psi_i(t)| {}^{\cos}_{\sin} [w_0 t + \theta_i(t)].$$

Here:

$$\theta_i(t) = \begin{cases} 0 & \text{if } \Psi_i(t) \geq 0 \\ \pi & \text{if } \Psi_i(t) < 0. \end{cases}$$

Thus, the pulse response $h_i(t)$ of the i-th orthogonal high-frequency filter is a radio signal with carrier $w_0/2\pi$, modulated in amplitude by the law $|\Psi_i(t)|$ and which has phase manipulation in accordance with $\Theta_i(t)$. Implementation of pulse responses of this type in an AO correlator (fig. 1) entails no fundamental difficulties since preparing 2N reference transparencies of different structure is enough for this (N is the number of terms in the orthogonal series implementable in the device). However, the high-frequency range, the solution to this problem encounters considerable technological difficulties that can be completely overcome by using the two-dimensional reference transparency described in [4, 5]. This transparency consists of a set of coding and carrying transparencies superimposed on each other. The first is described by the binary two-dimensional function of transmittance and defines by its structure the law of FM and AM of the recorded signal. The second is a homogeneous diffraction grating rotated relative to the optical axis Z of the device (fig. 1) by a small angle. The spatial period of the grating along the x axis defines the carrier of the recorded signal.

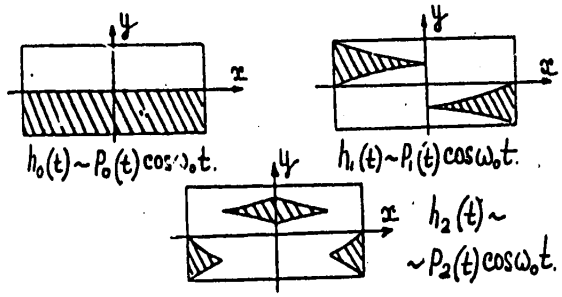

Fig. 2.

Shown for example in fig. 2 are the structures of the two-dimensional reference transparencies corresponding to the first three orthogonal Legendre polynomials of the first kind $P_0(x) = 1$, $P_1(x) = x$, $P_2(x) = 0.5(3x^2 - 1)$. The shaded areas are the regions of transmittance of the coding masks.

Thus, in a system of an AO correlator with two-dimensional reference transparency, implementation of orthogonal high-frequency filters is very promising. Indeed, in the first place, the necessary multichanneling is easily implemented; second, the appropriate pulse response is easily synthesized in a single channel on the base of the two-dimensional reference transparency; and third, the AO devices offer great possibilities in terms of increasing speed.

In conclusion, let us note that there are two factors that limit the possibilities of synthesizing orthogonal filters by the emthods of acousto-optics. They include the limited duration of recordable reference signals and the significant level of internal noises. However, the advantages, mentioned above, of AO orthogonal filters as well as the progress achieved in overcoming the noted shortcomings [6] permit the expectation that AO filters will find efficient application in solving problems entailing othogonal filtration.

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IMPROVING SIGNAL-TO-NOISE RATIO IN ACOUSTO-OPTICAL SPECTRUM ANALYZERS

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[Article by T. N. Sergeyenko and V. I. Yakovlev]

[Text] Annotation

A possible alternative for improving the dynamic range of acousto-optical spectrum analyzers is considered. The method entails narrowing the band for passage of the receiving path which is achieved by incorporating additional deflection of one of the light beams participating in the optical heterodyning.

In recent years, acousto-optical spectrum analyzers have begun to be used in various fields of radio engineering. However, more extensive application of them is hindered by the limited dynamic ranges of both the acousto-optical modulators used as the input device and the matrices of the photo detectors that convert the light distributions into electrical signals.

There are a number of engineering solutions [1, 2] aimed at extending the dynamic range of the photo detectors in the analyzers that generate the energy spectra of the signals being received.

In this paper, we discuss a possible alternative for improving the dynamic range of acousto-optical spectrum analyzers in which the output signal is generated as a result of the interference of two light beams on the photo sensitive surface of the photo detector [3, 4]. Photo multiplier tubes are mainly used as the photo detectors since in the spectrum analyzers in question, broad-band photo detectors with considerable dimensions of the light sensitive surface have to be applied. The signal-to-noise ratio [SNR] at their output has to be improved to improve the dynamic range of the spectrum analyzer.

It is known [5] that the SNR in optical heterodyning is defined by the relationship:

$$\frac{P_c}{P_{ш}} = \frac{\eta}{h\nu} \cdot P_c \frac{1}{\Delta f_{ф.п.}},$$

where η is the quantum efficiency of the photo cathode, h is Planck's constant, ν is the light frequency, P_c is the power of the signal light beam and $\Delta f_{ф.п.}$ is the band of the photo detector path. This formula is valid for the small power of the signal light beam compared to the power of the reference beam. It follows from it that the SNR of the photo detecting path can be improved by increasing the power of the signal and consequently the reference beams, or by narrowing the path bandwidth. The first method entails increasing the power of the laser and is undesirable. Therefore, the second method is more expedient.

Fig. 1 shows a diagram of an acousto-optical spectrum analyzer in which the band of the photo detecting path Δf_{pdb} is not tied to the band of the radio signals to be analyzed and can be made considerably narrower than the latter. Its minimum value is determined mainly by the transient processes in the electrical circuits.

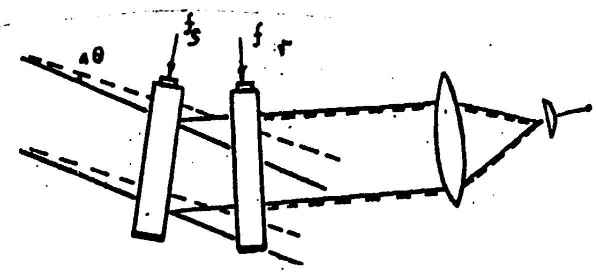

Fig. 1. Diagram of acousto-optical spectrum analyzer

The main units in the spectrum analyzer are two acousto-optical modulators made of identical material. The first modulator, the signal, is used to input the signal to be analyzed. The second, the reference, is used to input a signal with a frequency varying in time according to the linear law. This signal creates a reference light beam scanning in the plane of recording within the band of spatial frequencies to be analyzed. A condition for obtaining a signal at the output of the analyzer is the collinearity of the reference and signal beams. However, as shown in the diagram, the central frequencies of the modulators differ from each other by the value of $(f_s - f_r)$. Therefore, when the velocities of propagation of the ultrasonic waves in the modulators, V, are equal, collinearity is achieved by the modulators being illuminated by different light beams being propagated at an angle $\Delta\theta$ to each other. To ensure collinearity, this condition has to be met:

$$\frac{\lambda f_s}{V} = \frac{\lambda f_r}{V} + \Delta\theta$$

As a result of heterodyning, at the output of the photo detector a signal will be generated with the central frequency

$$f_{ph.\ det.\ band} = f_{sig} - f_{ref}. \qquad (2)$$

Making use of relationship (1), we can derive

$$f_{ph.\ det.\ band} = \frac{V}{\lambda}\Delta\theta. \qquad (3)$$

Hence it follows that the central frequency of the photo detecting path and its band are not a function of the central frequency and band of the signals to be analyzed. This permits narrowing the band of the photo detecting path and improving the SNR.

This result is explained by the fact that when the input signal frequency is changed by the value of Δf, the frequency in the reference signal must be shifted by the same value to obtain the condition of collinearity.

The scheme described above was studied experimentally. To generate two light beams at the input of the modulators, we used a diffraction grating with subsequent filtration of the unusable diffraction orders. The central frequencies selected for the modulators were 27 MHz and 31 MHz. Two harmonic oscillations with frequencies of 24 MHz and 30 MHz were input to the signal modulator. An LG-75 laser was used as the light source and the FEU-27 served as the photo detector. Connected to its output were band-pass filters with various band widths having a central frequency of 5 MHz.

Shown in fig. 2a [not reproduced] are the output signals from a spectrum analyzer with a filter band of 6 MHz. It can be seen that they are practically indistinguishable in the noise background. This is due to the low level of power of the beams being heterodyned. Improvement in the SNR was observed when the filter bandwidth was narrowed (in the process, the frequencies of the input signals and power of the beams being heterodyned were not changed).

Fig. 2b [not reproduced] shows a filter band of 1 MHz, and fig. 2c [not reproduced] a band of 100 kHz. The results obtained indicate the effectiveness of the described method.

In conclusion, let us note that this method permits making use of a photo detecting path with a band in a unit of megahertz in analyzing signals in the SVCh [microwave] range.

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DETERMINING TIME POSITION OF COMPLEX SIGNALS WITH LONG DURATION BY ACOUSTO-OPTICAL CONVOLVERS

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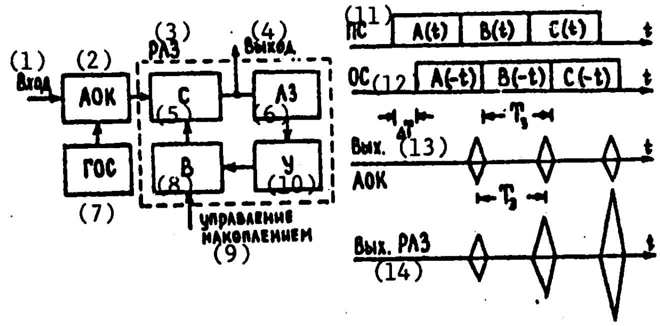
[Article by A. V. Kuzichkin]

[Text] Annotation

The problem of searching for complex signals of long duration by using a system of an acousto-optical convolver and a recirculating delay line is considered. Evaluations are made of statistical characteristics of procedure for determining the time position of complex signals received in a background of Gaussian noise.

Searching for and receiving complex radio signals under the conditions of uncertainty of their time position is one of the most interesting fields of application of acousto-optical convolvers (AOK) [1]. In cases when the duration T_c of signals being received (PS) does not exceed the signal delay time T_3 in the region of the acoustooptic interaction of the acoustooptic convolver, the acoustooptical processor is almost an asynchronous processing systems and permits determining the time position of complex signals (SS) with one-two cycles of their reception. Very often, however, the duration of complex signals is considerably greater than the delay time T_3, and then to eliminate energy losses that occur in acoustooptical processing of complex signals with long duration, coherent storage of convolver responses are utilized by using recirculation delay lines (RLZ) [2] or photo-PZM [expansion unknown] [3]. As aresult of this, the acoustooptic processor loses invariance to the time position of the PS [signals being received] and requires use of special procedures for synchronization.

Evaluated in this work are the capabilities of rapid searching for complex signals by the combined processing systems of the acoustooptical convolvers and recirculation delay lines. The structural diagram of the system in question is shown in fig. 1, where GOS is the reference signal generator, S is the summer, LZ is the delay line, U is the amplifier, and V is the gate controlling the duration of the period of the storage of the signals output from the acoustooptical convolver to the recirculation delay line. The preference given to the use of recirculation delay lines as accumulators is due to the circumstance that in the majority of real cases, the application of recirculation delay lines permits obtaining the required



Key:
1. input
2. AOK [acoustooptical convolver]
3. RLZ [recirculation delay line]
4. output
5. S [summer]
6. LZ [delay line]
7. GOS [reference signal generator]
8. V [gate]
9. storage control
10. U [amplifer]
11. PS [signals being received]
12. OS [reference signals]
13. acoustooptical convolver output
14. recirculation delay line output

Fig. 1

duration of the storage interval (to several milliseconds), and implementation of an acoustooptical processor with recirculation storage is considerably simpler than using photo-PZS [charge coupled devices].

In the most general case, the procedure for searching for complex signals by using the acoustooptical convolver and recirculation delay line consists in serial step correlation analysis of the signals being received with various values of reference signal delay. The decision on detection of complex signals is made according to the maximum of the signal output from the recirculation delay line after analysis of the entire range of time ambiguity of the signals being received. An estimate of the speed of successive searching for complex signals by the acosutooptical convolver and recirculation delay line system was made before the next mode of system operation. The size of the range of acoustooptical interaction of the acousto-optical convolver was chosen in such a way that for processing complex signals with duration T_c, an integer of recirculation loops is required: $R = T_c/T_3$. The signal being detected is formed by repetition of the complex signal formed according to the law of the same pseudorandom sequence. The reference signal is formed by splitting the initial complex signal into R segments, with duration T_3 each, and by time inversion of the segments obtained. The start of the recirculation period coincides with the start of the first reference signal segement. The reference signal is detected in a background of white Gaussian noise with zero mean and correlation function $1/2 N_0 \delta(t_2 - t_1)$.

In operation of the processing system under such conditions, the value of the correlation peak (KP) of the signal output from the recirculation delay line and the time of its emergence are a function of the time mismatch ΔT between the start of the signal being detected and the reference signal:

$$i_{KP} = \begin{cases} k_0 E_c (1 - |\Delta T| / 2T_3) & \text{for } \Delta T \in [-2T_3,\ 2T_3], \\ 0 & \text{for remaining values of } \Delta T,\ \Delta t_{kp} = T_c - \Delta T/2, \end{cases}$$

where E_c is the energy of the signal being detected in duration T_c, k_0 is the constant factor of proportionality and $\Delta T \in [-T_c/2,\ T_c/2]$.

Let us evaluate the search system speed by th mean quantity of periods of the complex signal, the detection of which is necessary to determine the time position of the signal being detected:

$$\overline{Q} = R/l\ P_{pr},$$

where $l = \Delta T_{step}/T_{delay}$, ΔT_{step} is the search step (value of time shift of reference signal in serial investigation of the zone of the possible time position of the signal being detected) and P_{pr} is the probability of the proper determination of the time position of the signal being detected after one-time analysis of the entire range of its ambiguity:

$$P_{np} = 1 - \prod_{i=1}^{m} (1 - P_i);$$

$$P_i = \int u \exp[-(u^2 + h_n^2)/2]\, I_0(h_n u)\, [1 - \exp(u^2/2)]^M du;$$

$$h_n^2 = 2E_n/N_0;\ E_n = E_c(1 - |\Delta T|/2T_3);\ h_0^2 = 2E_0/N_0;\ m = 2^{2/l},$$

$I_0(\cdot)$ is a modified Bessel function of the first sort of zero order, $M = B - 4$ for $l = 1$, $M = B - 2$ for $l = 2$ and B = base of the complex signal.

The results of calculation of the dependence of $\overline{Q}$ on the number of recirculation loops R and the
energy excess of the signal being detected h_0^2 are shown in the table. Table data are derived for a signal with the base 16384. The speed of the serial procedure for determining the time position of the complex signal was investigated for two search steps $\Delta T_{step} = T_{delay} (l = 1)$ and $\Delta T_{step} = 2\ T_{delay} (l = 2)$. Also, evaluation of the value of $\overline{Q}$ was made for the case of the most unfavorable search conditions (value of $\overline{Q}$ is given in the denominator) and for the case of the best search conditions (value of $\overline{Q}$ is given in the numerator). The difference of these cases consists in the different values of the current time mismatch ΔT. Thus, when $\Delta T = 0$, the decision on detection of the complex signal is made by the correlation peak of the highest value ($h_p^2 = h_0^2$), and under unfavorable conditions, the decision is made according to the correlation peak of the significantly lesser value ($h_{p\ min}^2 = (0.5 \div 0.7)\ h_0^2$).

From the results obtained, it can be seen that with relatively small values of h_0^2 (less than or equal to 10), the highest speed of searching for a complex signal is reached with the search step equal to T_{delay}. But in the case of detection of signals under the conditions of a large energy excess of a complex signal (h_0^2 greater

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R	$\ell=1$			$\ell=2$		
	$h_0^2=10$	$h_0^2=20$	$h_0^2=30$	$h_0^2=10$	$h_0^2=20$	$h_0^2=30$
64	43I / 566	I04 / I26	70 / 74	279 / 844	63 / I04	39 / 52
I28	862 / II3I	208 / 253	I40 / I48	558 / I688	I26 / 207	78 / I04

than or equal to 20), for rapid determination of the time position of the signal being detected, it is advisable to use a search with a step of $2T_{delay}$. The mean duration of the procedure for detecting complex signals in this case is close to $RT_c/2$, which is faster by the factor of B/R than when complex signals are searched for by using conventional correlation detectors [4].

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BANDWIDTH EVALUATION IN OPTICAL INFORMATION PROCESSING SYSTEMS

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[Article by K. Ye. Rumyantsev and V. S. Firsov]

[Text] Annotation

The value is determined for the optimal bandwidth of the detecting channel in a light pulse detector, the value of which differs substantially from that recommended in the radio range.

Constructing photo detectors of the FEU [photo multiplier] type with a bandwidth of more than 50 MHz for optical information processing systems is a rather complex problem. In connection with this, it has become necessary to examine the possibility of applying photo detectors with a limited bandwidth in systems for detecting nanosecond pulses t_u.

In [1, 2], an expression was dervied to describe the shape of single-electron pulses of a photo multiplier under the condition of exponential distribution of time of transit by electrons of the interdynode spacing, zero initial velocity and no space charge. For a photo detector with N identical multiplying stages and a constant exponential distribution τ, the pulse characteristics of the photo multiplier are defined by the expression:

$$h_1(t) = \frac{1}{\tau\Gamma(N+1)}\left(\frac{t}{\tau}\right)^N \exp\left(-\frac{t}{\tau}\right), \qquad (1)$$

where $\Gamma(x)$ is a gamma function.

Knowledge of the analytic expression (1) for describing the frequency response permits defining the effective photo detector bandwidth:

$$\Delta f_{эфф} = \frac{1}{4\sqrt{\pi}\,\tau}\,\frac{\Gamma(N+0.5)}{\Gamma(N+1)}. \qquad (2)$$

The shape of the electrical pulse at the output of the photo multiplier upon reception of a light signal with a rectangular envelope can be described by the formula:

$$\mu(t) = 1(t)\frac{\Gamma(N+1, t/\tau)}{\Gamma(N+1)} - 1(t-t_u)\frac{\Gamma(N+1, t-t_u/\tau)}{\Gamma(N+1)}, \quad (3)$$

where $\Gamma(p,x)$ is an imcomplete gamma function, and $1(t)$ is a step function.

Here the pulse amplitudes are normalized relative to the signal at the output of the photo multiplier in the prescribed mode with the effect on input of a drop in light intensity.

Upon detection of a pulse light signal, the spectral density of the noise current at the output of the photo multiplier is limited to the frequency response of the latter, and the fluctuating process is nonstationary, varies in time and is dependent on the value of the photo current. The mean square of the random process at the output of the photo detector B(t,t) with pulse response (1) can be found by the formula:

$$\frac{B(t,t)}{\sigma^2} = 1(t)\frac{\Gamma(2N+1, 2t/\tau)}{\Gamma(2N+1)} - 1(t-t_u)\frac{\Gamma(2N+1, 2(t-t_u)/\tau)}{\Gamma(2N+1)}, \quad (4)$$

where $\sigma^2 = 2e^2\mu^2(1+\theta)\bar{n}\Delta f_{эфф}/t_u$ is the dispersion of the fluctuating current of the photo detector, e is the electron charge, μ is the factor of multiplication of the secondary photo multiplier, $(1+\theta)$ is the coefficient that corrects for the noise of the secondary-emission multiplication of the photo multiplier, and $\bar{n}$ is the mean number of photons detected within a light pulse duration.

Knowledge of the noise and frequency responses of photo detectors permits switching to the problems of optimization of the bandwidth of the detecting channel in the mode of detection of light signals. The detector picks out the maximal value of the fluctuating process at the output of the photo detector within the observation interval and compares it to the threshold level. The instantaneous values of current fluctuations at the output of the detector are considered distributed according to the normal law with mean dispersions:

$$m_0 = e\mu\bar{n}_\varphi/t_u \;;\; \sigma_0^2 = 2e\mu(1+\theta)m_0\Delta f_{эфф}, \quad (5)$$
$$m_1 = m_0(1+K_m q);\; \sigma_1^2 = \sigma_0^2(1+K_\sigma q),$$

respectively, on the assumption of fulfilling the hypothesis on the absence or presence of a signal in the analyzed time interval. Here, $\bar{n}_\varphi$ and $\bar{n}_c$ is the mean number of photons of the background and signal radiations detected within the light pulse duration, and $q = \bar{n}_c/\bar{n}_\varphi$ is the signal and background radiation power ratio.

The coefficients K_m and K_σ represent the maximum values, corresponding to expressions (3) and (4).

The decision on the presence of a signal in the analyzed time interval is made when the process exceeds the threshold level C, the value of which is found according to the given probability of a false alarm [$P_{\Lambda T}$]:

$$C = m_0 + \sigma_0 \Phi^{-1}(1 - P_{\Lambda T}), \quad (6)$$

where $\Phi^{-1}(x)$ is the function, inverse to

$$\Phi(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} \exp(-t^2/2)\, dt.$$

Considering relations (2), (5) and (6), let us find the equation for the detector performance:

$$P_{обн} = \Phi\left(\frac{q\sqrt{\frac{F}{t_u}}\, z - \Phi^{-1}(1 - P_{\Lambda T})}{\sqrt{1 - K_m q}}\right),$$

where $z = \sqrt{\frac{2\sqrt{\pi}}{1+6} \cdot \frac{\Gamma(N+1)}{\Gamma(N+0.5)}\, \bar{n}_y}$.

The relationships shown in the figure indicate the existence of an optimal value of the bandwidth of the detector channel Δf_{opt} which minimizes the probability of missing a signal. However, the value of the latter differs substantially from that recommended in the radio range.

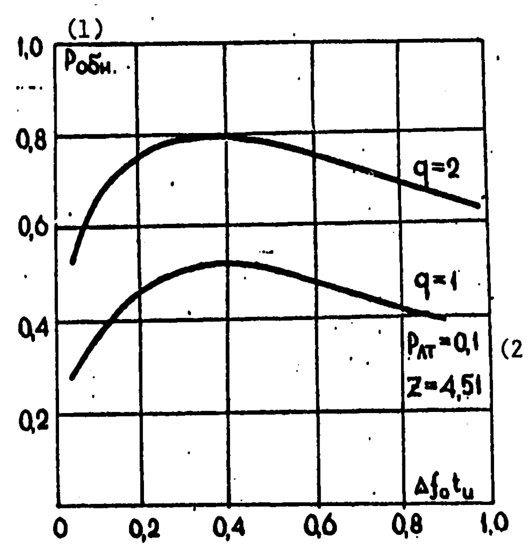

Fig. Relationship between detector bandwidth and detector performance with fixed values of false alarm probability, q and z.

Key:
1. detector performance
2. false alarm probability

Table. Signal Miss Probability

z	$\Delta f_{opt} \cdot t_u$	Отношение сигнала к фону signal-to-background ratio		
		2	5	10
2,3	1 optimum 0,15	0,56 0,47 0,54	0,31 0,17 0,21	0,13 0,035 0,045
5,2	1 optimum 0,15	0,29 0,13 0,2	0,027 0,0037 0,005	0,0013 $2,7 \cdot 10^{-6}$ $5,4 \cdot 10^{-8}$

Selecting the band of $1/t_u$ would lead not only to significant complication of the entire amplifier channel, including the photo detector, but would also yield an excessive value for the signal miss probability, P_m (see table). Thus, for example, when $z = 5.2$ and $q = 20$, the difference in the value of the P_m would be more than 14 orders.

Let us note the weak variation in the value of the detection probability in the neighborhood of the optimal bandwidth which permits an additional reduction in the band without substantially impairing the probability characteristics. This permits designing amplifier channels including photo detectors with high amplification.

A feature of optical systems is that the optimal bandwidth value is a function of the value of the signal and background radiation power ratio. Thus, while when $q = 2$, the optimal bandwidth value is 0.33 t_u, when $q = 10$, it is 0.24 t_u and when $q = 40$, it is only 0.18 t_u.

Thus, we have shown a substantial difference between the optimal bandwidth for the detecting channel in a light signal detection system and that recommended in the radio range and the dependence of the latter on the signal and background radiation power ratio.

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OPTICAL PROCESSING OF SIGNALS WITH ENHANCED RESOLUTION IN NONCOHERENT LIGHT. OPTICAL SYSTEMS WITH FIXED REFERENCES USING NONCOHERENT LIGHT FOR REAL-TIME SIGNAL PROCESSING

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[Article by V. V. Gushchin, E. M. Zuykova and S. N. Rubtsov]

[Text] Annotation

The possibility of increasing the resolution of devices for processing information in noncoherent light through two-dimensional representation of the signal at input to the processing system is discussed.

In a number of problems in radio physics, it is necessary to perform spectral analysis with a resolution that is considerably beyond the capabilities of existing spectrometers. This is primarily true for problems involving measurement of the width of a spectral line, studying wideband signals and isolating harmonic signals in a background of noise.

The resolution of conventional spectral analyzers is limited to the width of the input aperture according to time or a coordinate, i.e. the duration of the realization subjected to spectral analysis and the number of frequency channels. This shortcoming may be overcome if, for example, a two-dimensional optical spectral analysis and raster recording of the signal at input are made use of [1]. The recording can be obtained, for instance, by photographing the raster from a CRT screen generated by a line-by-line breakdown of the signal which modulates the CRT beam in intensity. A two-dimensional spectral analysis of the recording obtained can be performed in both coherent and noncoherent light [1, 2]. As a result of spectral analysis in the direction of the K_x axis, the resolution $2\pi/D_x$ is obtained, where D_x is the raster line length; in the direction of K_y, we have a set of comb filters with the resolution of $1/ND_x$, where N is the number of lines in the raster. If at the input we have the sinusoidal signal of the spatial frequency K, then at the output of the analyzer, K can be represented in the form of $K = n2\pi/D_x + \Delta K$, where ΔK lies within the interval $[-\pi/D_x, +\pi/D_x$. The first term in the expression yields the rough value of the frequency, and the second, the precise. A similar two-dimensional spectral analysis can be obtained without advance recording on photographic film in optical processing schemes with time integration. From now on we shall be discussing only this type of system [3].

Shown in fig. 1 is a diagram of a two-dimensional Fourier transform with fixed references in noncoherent light [4]. Used as input 1 is a CRT "without storage" that is placed at the input of the optical spectral analyzer, assembled according to the scheme of the Meyer-Eppler two-dimensional correlator with fixed transparencies, zonal Fresnel plates of the type $\cos\alpha(x^2 + y^2)$. One zonal plate is placed on the CRT screen, the other at some distance d in plane 2. The light beams emitted by all input elements are uniformly distributed relative to the normal to the source in the effective range of the angles and modulated by the first and second transparencies. Corresponding to the various beam directions are the various delays of the first plane relative to the second. By the end of the recording of the raster on multichannel integrator 4, placed in the focal plane of lens 3, the function of correlation of the images of planes 1 and 2 is generated.

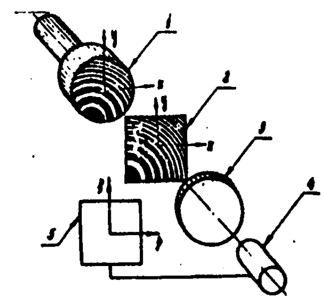

Fig. 1.

The informative part of the correlation function is a two-dimensional Fourier transform of the type:

$$\Phi_1 \sim \iint_{D_x D_y} f(x,y)\cos(K_x x + K_y y + \varphi)\,dx\,dy, \qquad \text{(I)}$$

where f(x,y) is the raster recording of the signal at input, $K_y = \alpha\eta$, $\xi = -\frac{d}{F}x$, $\eta = -\frac{d}{F}y$ and F is the focal distance of lens 3. Compared to spectral analysis of the raster recording on photographic film, in this method storage from input is transferred to output. The system operates in real time with no delay since the result of the analysis is obtained by the end of the recording of the realization. The frequency range of analysis is determined by the scanning speed. However, the maximum number of elements of resolution for the K_x and K_y axes is limited to the diffraction effects and may be $\sim 50 \times 50 \approx 2000$, if we consider the minimum resolvable element equal to $a\sqrt{\lambda d}$. With that, the dynamic range is $\sim$ 26 db.

Another method of two-dimensional spectral analysis with time integration can be implemented according to the scheme of a two-dimensional correlator (fig. 2) with movable transparencies, two zonal Fresnel plates 3 and 4. The product of the transparencies contains the component $\Phi_1(t) \sim \cos(\alpha\xi x + \alpha\eta y + \varphi_1)$, where $\xi = v_x(nT - t)$, $y = v_y t$.

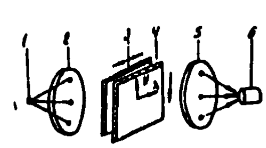

Fig. 2.

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Displacement along the x axis is reciprocating according to the sawtooth law, while along the y axis it is uniform:

$$\Phi_1(t) \approx \cos(\alpha v_x x t + \alpha v_y y t + \varphi_0), \qquad (2)$$

where $w_x = \alpha v_x x$ is the rough, and $w_y = \alpha v_y y$ is the precise value of the frequency. The plane of such a transparency is the raster of time frequencies. In the scheme shown in fig. 2, the signal, varying in time, modulates in brightness input 1, which by lens 2 uniformly illuminates the plane of reference 3 and 4. Then the reference plane is projected by lens 5 to the multichannel time integrator 6, where the signal spectrum is represented at coordinates w_x, w_y. The shortcoming with this type of analysis is the limitation on the frequency range at the top because of the use of mechanical displacement and the complexity of making the reference standard.

Another method of analysis is possible with a simpler reference standard of the best quality but requiring a greater number of elements. This is the use of multichannel optical analyzers of the spectrum with the reference standard of cos xt, which can be implemented in the form of a rotating disk or crossed optical gratings. A wideband signal is divided into a series of signals with a narrower band by using electric filters. The signals go from the electric filters to the light modulators and spectral analysis is performed simultaneously from all modulators.

Another method is the use of two series connected multichannel optical spectral analyzers. With that, one can make use of schemes with time integration both with movable and fixed reference standards. Two schemes of analysis are possible with the series connection.

In the first case, initially subjected to analysis is the result of the time quantization of the signal at a frequency that does not satisfy the sampling theorem [5]. With that, the signal spectrum is not uniquely defined. Ambiguity is eliminated by secondary spectral analysis of the phase structures in the series of spectral realizations of the quantized signal. The scheme of such analysis is shown in fig. 3 [5]. In this scheme, the signal being analyzed f(t) modulates the light of input device 1 in intensity. The variable component of the plane of the reference mask 4 is $\sim \cos \alpha(x)t$. Lenses 3, 5 and 9 effect the projection of planes 1 to 7 along the y axis and 7 to 11 along the x and y axes. A set of realizations of the spectrum is obtained at the output of the multichannel time integrator 11. Fig. 3b illustrates the spectrum at the coordinates w and channel number n of a sampled Doppler signal reflected by scatterers distributed in some volume. If a continuous signal f(t) is fed to input device 1 and it is scanned

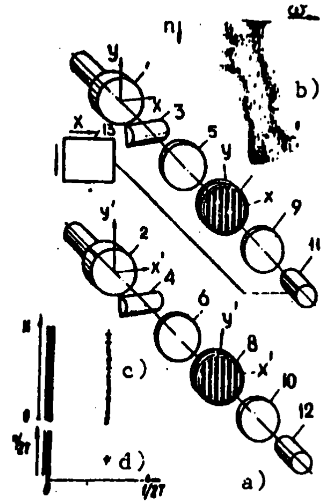

Fig. 3.

along the y axis for time T, then analysis of an individual resolvable element on the y axis is equivalent to analysis of the input signal quantized with the scan frequency. Fig. 3c illustrates the result of the primary spectral analysis of the harmonic signal. Plotted on the horizontal axis is the frequency corresponding to the value of the frequency of the signal ambiguously within the range 1/2T. Derived on the vertical N axis is the distribution of the phases of the spectral realizations. A secondary spectral analysis along the N axis is performed by the system similar to that discussed below and consisting of elements 2, 4, 6, 8, 10 and 12. Fig. 3d illustrates the result of analysis of the harmonic signal at output 12 at the coordinates of the rough frequency value n/T and the precise frequency value within the range of 1/2T.

The frequency response of such a system can be represented in the form of:

$$\Phi_1(x,y) \sim \frac{\sin N\left(\omega_0 - \alpha_1(x) - \frac{2\pi n}{T_{всп}}\right) T_{всп}/2}{\sin\left(\omega_0 - \alpha_1(x) - \frac{n 2\pi}{T_{всп}}\right) T_{всп}/2} \cdot \frac{\sin M\left(\frac{2\pi k}{T_{всп}} - \alpha_2(y) - \frac{2\pi m}{T_{стр}}\right) T_{стр}/2}{\sin\left(\frac{2\pi k}{T_{всп}} - \alpha_2(y) - \frac{2\pi m}{T_{стр}}\right) T_{стр}/2}, \qquad (3)$$

where $\omega = \omega_0 + \frac{2\pi k}{T_{всп}}$, $T_{всп}$ is the auxiliary scan in the first stage of analysis and $T_{стр}$ is the scan during the reading in the second stage of analysis.

The second method of analysis with series connection of two multichannel analyzers is as follows: obtaining in the first stage the current spectrum (rough analysis), and then refinement of the frequency in the second stage by spectral analysis along the coordinate of the current spectrum.

With two-stage analysis, the number of independent frequency channels is $\sim 10^4$ and the dynamic range is $\sim$ 30 db. It should be noted that the two-stage analysis can be replaced by one stage if the product of reference standards of the type $\cos k_y y$ and $\cos w_x t$ is used.

A special case of analysis with enhanced resolution is analysis on the intermediate frequency (fig. 4). In the scheme shown in fig. 4, the signal fed to modulator 1, CRT with scan along the y axis, is in addition turned around the x axis synchronously with the intermediate frequency. Synchronism results in the brightness marks of the signal being shifted on the CRT screen along the auxiliary scan from frame to frame. The rate of their shifting and the direction depend on the value and sign of the signal frequency relative to the intermediate.

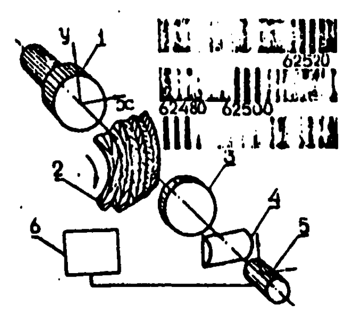

Fig. 4.

Reference standard 2 has the form: $\cos(\alpha(x)t - K_o x$, where K_o is the spatial frequency along the x axis, proportional to the intermediate spatial frequency K_{np}. As the reference standard, we can make use of, for example, a rotating disk with multitrack recording of the various spatial frequencies on the disk circle. In doing so, the track numbers are placed on the x axis and the number of periods in each track on the x axis equals the number of periods of the intermediate frequency in the auxiliary scan. To determine the sign of the difference between the signal and intermediate frequencies, each frequency track is recorded twice so that the phase of the reference standard signal decreases as the disk rotates in one track, but increases in the other. Behind disk 2 at some distance from it on the z axis, the correlation function is obtained along the x axis in the converging light between the recording on the CRT and the reference standard signal on each track of the reference disk. Then the astigmatic system 4 projects on the y axis the CRT screen, and on the x axis, the plane of correlation to the multichannel integrator 5. In the multichannel integrator, independently for each point of the y axis, the maximum output is obtained from that reference standard track for which the sign and time frequency of the reference standard coincide with the sign and frequency of the signal.

The frequency response from output 5 can be represented in the form of:

$$\Phi_2(x,y) \sim \frac{\sin(K_{np}-K_o)D/2}{(K_{np}-K_o)D/2} \cdot \frac{\sin M(\omega \pm \alpha(x) - \frac{m 2\pi}{T})T/2}{\sin(\omega \pm \alpha(x) - \frac{m 2\pi}{T})T/2}, \quad (4)$$

where T is the duration of the scan for the y axis, D is the dimension of the window of integration for the x axis and MT/2 is the integration time. Fig. 4 on the right illustrates the result of analysis of two signals with frequencies differing by ±20 Hz on the intermediate frequency of 62,500 Hz and of the constants on the y axis on the input CRT 1. With analysis on the intermediate frequency, the problem of separating the response to the signal from the response to the constant component is made easier because the filling of the response to the signal corresponds to the number of periods of the intermediate frequency in the auxiliary scan, and this filling does not exist in the response to a constant component. Therefore, the dynamic range of analysis on the intermediate frequency is ~ 30 db and is mainly determined by the nonlinearity of the characteristic of the input CRT in luminance.

In conclusion, let us note that in the methods we have discussed above for analysis of signals with enhanced resolution, the requirement on the precision of making the reference standard is not 1/M, where M is the maximum number of points in the spectrum, but $1/\sqrt{M}$. With that, the precision of 1/M is imposed on synchronization of scans or separation of the realization into parts which are then analyzed with the precision of $1/\sqrt{M}$.

In such systems for spectral analysis with enhanced resolution, one can also effect matched filtration of signals with linear frequency modulation, processing of signals from antenna arrays and others if the reference standard is changed in the appropriate way.

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OPTICAL METHODS OF PROCESSING SIGNALS FROM SEISMIC SOURCES

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[Article by V. V. Gushchin and A. I. Khil'ko]

[Text] Annotation

Optical devices are described that permit measuring the fine structure and phases of spectral components of a signal from seismic sources.

Application of optical analyzers in processing seismic data usually involves spectral-correlation analysis of seismic courses. And the main advantage of optical methods is in the capability of simultaneous processing of a large number of channels. This advantage of optical systems can be used to determine the fine structure of the spectrum of signals from seismic sources. For this, the source unidimensional signal is represented in two-dimensional form by the densities of the "line by line" recording, which permits processing a realization of long duration [1]. Fig. 1 shows a diagram of a high-resolution coherent spectrum analyzer. A two-dimensional transparency with a recording of the signal is illuminated by a converging spherical wave, and with that, the two-dimensional signal spectrum is generated in the spectral plane. The spectrum with a resolution of 2 Hz is derived (the so-called rough frequency) on one axis, and a resolution of 10^{-3} Hz (precise frequency) on the other coordinate.

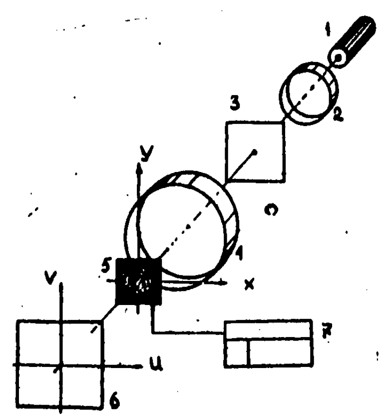

Fig. 1.

Fig. 2 illustrates the results of measuring the fine structure of the spectrum of the quasi-harmonic signal of the SV 10/100 seismic generator. Signal spectrum width is at its minimum when $T = T_{opt.} = 105$ s. This indicates non-stationary phase flucuations of the signal. Minimum spectrum width for the SV 10/100 generator, as follows from an experiment, is 0.0011 Hz. The capability of two-dimensional processing in optics can be used for measuring phase spectra of signals, which can be used in seismology for measuring dispersion characteristics of the environment.

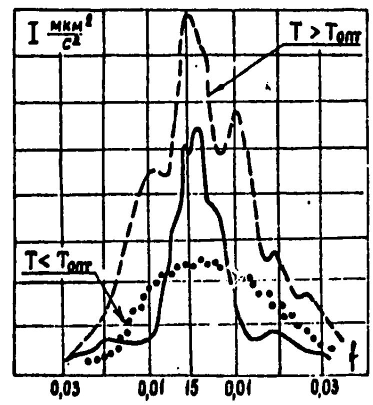

Fig. 2.

Fig. 3 is a diagram of a coherent analyzer of the phase spectrum. The signal to be analyzed is entered in density form in each channel simultaneously. In each channel, a special form filter cuts out an individual frequency, an image of which is built in the output plane [2]. By reading the spatial phase of each of the harmonics in the output plane relative to the selected system of coordinates, one can measure the phase spectrum of the signal.

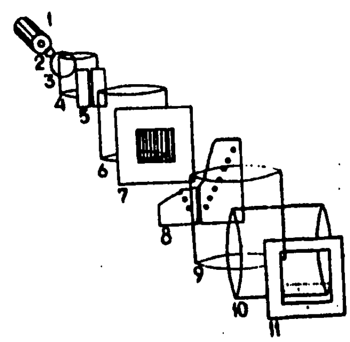

Fig. 3.

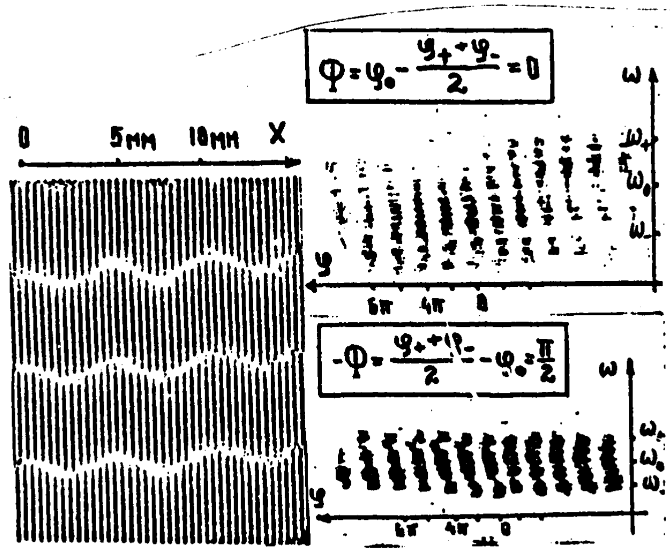

Fig. 4.

Fig. 4 illustrates the results of measurements of the phase invariant of a triharmonic wave propagated in a disperse medium [3]. Used as the triharmonic wave in this experiment was a sinusoidal wave with phase modulation. Shown for clarity is the moire structure derived when the signal with phase modulation is superimposed on itself. Shown in fig. 4 is the output plane of the analyzer for two values of the phase invariant, $\Phi = 0$ and $\Phi = \frac{\pi}{2}$.

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PRINCIPLES OF DESIGN OF OPTICAL DIGITAL COMPLEX FOR SEISMIC INFORMATION PROCESSING

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[Article by V. P. Ivanchenkov and P. V. Mineyev]

[Text] Annotation

Principles of design and structure are discussed for a hybrid optical digital complex (OTsK) on a base of optical computing devices and the "Elektronika NTs-03T" microcomputer with extended main storage.

A feature of seismic information is the large amount of data to be processed and stored. Computers and various specialized electronic devices are now used to process seismic data. Hybrid optical electronic systems are a new direction in the evolution of information computing resources for processing geophysical data; tehy permit raising system throughput and efficiency. Introduction of such systems into practice is substantially expanding the capabilities of performing on-line processing of seismograms under field conditions; it is intensifying the reverse effect of results of processing on the techniques and technology of performing geophysical operations.

Of considerable interest in this regard is the development, based on optical computer devices and microprocessors, of high-speed small computer systems that can be used for on-line analysis and preprocessing of data right with the seismic prospecting crew.

Fig. 1 illustrates a structural diagram of an optical-digital complex for processing seismic information obtained in the search for oil and gas. This system is based on the "Elektronika NTs-03T" microcomputer and an analog optical computer (AOV) with a spatial-noncoherent source of radiation.

Information is input into the system from a digital seismic prospecting station (SSTs) through an external unified bus (VUM) into the microcomputer or through a normalizing amplifier (NU) by using a spatial-time light modulator (PVMS) into the optical computer. Used as the light modulator is a light valve tube with a thermoplastic medium [1] on which data can be recorded for 20+30 physical observations (signal sample volume is $\approx 10^5$). Placed in the frequency plane of the optical

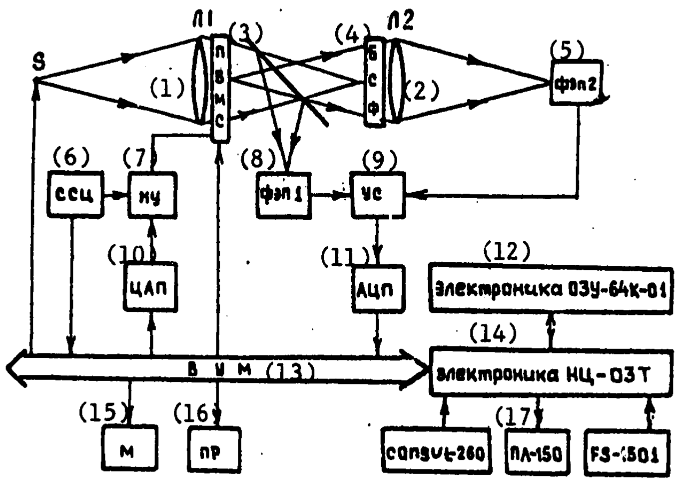

Fig. 1. Optical Digital Complex for Processing Seismic Information

Key:

1. L1 [lens 1]
2. L2 [lens 2]
3. PVMS [spatial-time light modulator]
4. BOF [unit of operation filters]
5. FEP2 [photo electronic converter]
6. SSTs [digital seismic prospecting station]
7. NU [mormalizing amplifier]
8. FEP1 [photo electronic converter]
9. US [interface units]
10. TsAP [digital-to-analog converter]
11. ATsP [analog-to-digital converter]
12. Elektronika OZU [main storage]-64K-01
13. VUM [external unified bus]
14. Elektronika NTs-03T
15. M [monitor]
16. PR [seismic section plotter]
17. PL-150

computer is the unit of operation filters, recorded on a photo medium or made in the form of special mechanical screens in performing filtration by frequency and apparent velocity. Optical processing results can be read out both in the frequency plane of the optical computer and in the plane of the image. To convert optical signals into electrical, it is proposed to make use of combined photo-electronic converters (FEP), in which the image is read out for one coordinate by oscillatory scanning of the mirror element, and for the second, by using a line of PZS [charge coupled devices]. Considering the large information capacity of an image frame at the output of the optical computer and the limited size of computer main storage, realization of two methods for data read out is provided for: frame-by-frame and offline frame-by-frame. Introduction of the second method for read out may also be determined by the selected mode of write-erase of information for the spatial-time light modulator [1]. In the frame-by-frame read-out method, information is coded according to elements of a matrix of 100x1000 positions. Each position is represented by 6+8 binary bits. From the photo-electronic converter outputs, the information is sent through an interface unit (US) and ATsP [analog-to-digital converter] to the computer for further analysis, processing and display of intermediate and

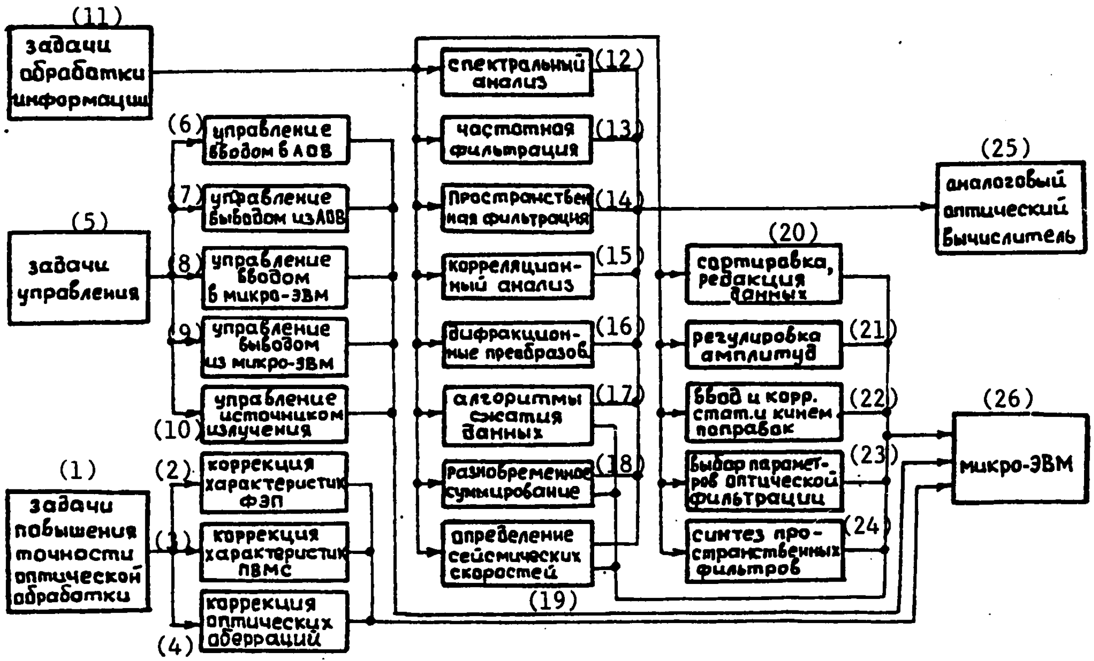

Fig. 2. Distribution of Operations between Analog Optical and Micro Computers

Key:

1. optical processing precision enhancement tasks
2. adjustment of photo-electronic converter characteristics
3. adjustment of spatial-time light modulator characteristics
4. adjustment of optical aberrations
5. control tasks
6. analog optical computer input control
7. analog optical computer output control
8. microcomputer input control
9. microcomputer output control
10. emission source control
11. information processing tasks
12. spectral analysis
13. frequency filtration
14. spatial filtration
15. correlation analysis
16. diffraction conversions
17. data compression algorithms
18. diverse summation
19. determination of seismic velocities
20. data sorting and editing
21. amplitude control
22. input and adjustment of static and kinematic corrections
23. optical filtration parameter selection
24. synthesis of spatial filters
25. analog optical computer
26. microcomputer

final results on the CRT monitor (M) screen or on the seismic section plotter (PR). To provide processing flexibility, the structure of the optical-digital complex provides for the capability of transferring information from the computer to the optical computer through a TsAP [digital-to-analog converter] and a NU [normalizing amplifier]. For data exchange between the optical analog and micro computers, the size of computer main storage must match the size of data to be read out, taking the signal coding word length into consideration. This is porvided for by connecting the "Elektronika OZU-64K-01" main storage unit to the computer.

The efficiency of application fo the optical-digital complex is largely determined by the rational distribution of functions between the optics and electronics and by the organization of data exchaneg between the digital and optical parts of the system in implementing a particular algorithm for seismic data processing. Based on an analysis of the basic procedures and graphs for processing of the seismic information [2] with regard to the specifics of implementation of hybrid computations in optical-digital systems, the class of problems solvable by the optical-digital complex and the distribution of functions between the analog optical and micro computers were defined. The distribution of operations between the analog optical and micro computers that is shown in fig. 2 permits implementation of a large number of processing algorithms, in the execution of which considerable difficulties occur in digital computers.

To evaluate the capabilities of the optical-digital complex in question, comparisons were made of the time expended to implement a typical graph for data processing by the method of the overall deep point [2] on the optical-digital complex and a medium-size computer. Of the various filtration procedures used in processing, only frequency filtration and filtration by velocity were considered in the evaluation. When all graph procedures are performed simultaneously, processing time on the optical-digital complex is one-sixth that on the medium-size computer. With complication of the graph and repetition of computational procedures, which as a rule is implemented in processing seismic data because of the inadequacy of a priori information on the properties of signals and noise, application of the optical-digital complex permits obtaining a more substantial reduction in time.

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CONFERENCES

THIRD INTERNATIONAL CONFERENCE 'DIAGNOSIS AND FAILURE-FREE SYSTEMS'

Kiev ELEKTRONNOYE MODELIROVANIYE in Russian No 1, Jan-Feb 81 p 105

[Article by V. A. Gulyayev]

[Text] The Third International Conference "Diagnosis and Failure-Free Systems" was held on 2-4 September 1980 in Kokotek Village near Katowice (Polish Peoples Republic).

Three sections worked at the conference--test generation and systems design with regard to the requirements of diagnosis, diagnosis of computer control systems and their software and diagnosis of microcomputers and automatic test equipment. Scientists from the CSSR, Polish Peoples Republic, Hungary, Yugoslavia, France, the USSR and other countries participated in the work of the conference.

Reports of A. Hlawiczki and D. Badury (Polish Peoples Republic) "Test Generation with Regard to Runup for Asynchronous Discrete Systems," of I. Piechi (Polish Peoples Republic) "Modelling at the Functional Level of Digital Units" and also the report of P. P. Parkhomenko (USSR) devoted to problems of finding malfunctions in complex systems were read at the conference. Methods of analyzing the reliability of automated control systems were considered in the report of V. I. Maksimov (USSR) and V. A. Gulyayev, A. D. Glukhov and A. K. Lisitchenko (USSR) and others reported on "Automated Design of Diagnostic Systems Based on an Applied Program Pack for Solving Graphic Problems."

The report of B. G. Wolik (USSR) was devoted to mathematical models for estimating the efficiency of complex systems.

Data on the automated test synthesis system GENTEST were presented in the report of I. Klimowicz and I. Szaniawski (Polish Peoples Republic) "Characteristics of Generation and Verification System for Tests of GENTEST Logic Networks." Deductive modelling was used in the system and the Roth algorithm was realized. All the programs were written in ASSEMBLER and PL-1 languages.

Problems of estimating the reliability of operating systems were considered in the report of D. Kaban Polish Peoples Republic) "Error Analysis of Operating Systems." G. Krawczek (Polish Peoples Republic) dwelt on problems of microcomputer testing in the report "Specifics of Microcomputer Testing."

Problems of selecting the recovery strategy for multiprocessor systems were considered in the report of A. Fridman (United States) "Recovery Strategy for Multiprocessor Systems."

The report of L. Bedkowski and W. Naigebuer (Polish Peoples Republic) "One Method of Structural Optimization of a System by the Maintenance Criterion Using Bellman's Principle" was devoted to structural optimization of systems by service criteria using the dynamic programming method.

Approximately 60 reports and communications devoted to various aspects of analysis and provision of the reliability of complex digital systems and devices, including problems of monitoring computer systems, organization of microcomputer checks, tester design principles and so on was heard at the sessions.

The results of research in the field of technical diagnosis and the reliability of digital systems were summarized at the conference and ways were noted for further developing research on this problem. The conference contributed to an exchange of opinions and strengthening of fraternal relationships between specialists of different countries.

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