DESIGN FEATURES OF THE "PIKHTA" PROCESSING SYSTEM

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We describe an automated measurement system complex designed for pollution control in the lower atmosphere and for measurement of its optical parameters.

The system includes a pulsed lidar, consisting of a transmitter and two receivers, a phase measurements unit, an aerosol particle size analyzer, and a microcomputer plus peripherals.

Modern atmospheric optics, both in subject matter and methodology, is concerned with the joint solution of direct and inverse problems[1] of the atmosphere. Among the most important conditions providing for the solution of both direct and inverse problems is the development and practical application of active laser remote sensing techniques must be mentioned first due primarily to their capability to provide real-time information about large atmospheric volumes with high spatial and temporal resolution. In turn, one of the most important factors facilitating successful development of laser remote sensing methods is the construction of highly sophisticated lidars, which are completely automated laser measurement systems capable of recording and processing laser return signals with high precision and in real time. The results obtained with such systems are presented in form convenient for users.

In developing the proposed design principles the authors have produced the "PIKHTA" measurement system, which is intended to monitor ground-layer pollution and measure the optical parameters of the atmosphere over short slant paths. System operation is based on atmospheric backscattering and reflection. The principal component of the measuring system is a multipurpose pulsed lidar containing a transmitter/receiver couple pair. Two wavelengths are used in this lidar, the first and second harmonics of a Nd:YAG laser. The system also includes a device for measuring the scattering phase function using the multipurpose lidar, a "SPECTR-3-ACh" aerosol particle-size analyzer, systems for recording and processing the signals, and a number of auxiliary devices.

We now give a brief short description of some of the subsystems.

1. The transmitter is a self-contained module consisting of an IZ-25 laser head and an RITM-150 power supply. The transmitter includes an independent laser-head cooling system that normally supports the delivery of pulse packets at a repetition rate up to 50 Hz, with intervals between packets not exceeding 5 minutes. The transmitter is controlled by signals coming from the microcontroller. The transmitter provides for manual firing of single pulses or triggering from an internal generator, which allows for independent operation of subsystems when tuning up and trouble-shooting the system. In order to control the output pulse power, to synchronize signal processing systems, and to coordinate operation of the scattering phase function meter, some of the radiation is directed into light guides which are terminated in fairly low-loss (< 2 dB) optical connectors mounted on the control pane1.

2. The receiver consists of an objective, beam-splitting optics, two photodetector modules (PMTs), signal processing circuitry, and the PMT power supply.

One outstanding feature of the receiver described here is its multichannel design, i.e., two or more photodetectors are involved in a common receiving system. This makes it possible to increase the signal-to-noise ratio, and hence to increase the accuracy of measurements. To enhance the utility of measurements and maximize the efficiency of use of lidar transmitter power, the backscattered signals in each photodetector are recorded at two wavelengths (0.53 and 1.06 mm).

The amplitude of received signals is measured to an accuracy of better than 10% over a dynamic range of at least 10^4. High measurement accuracy over a wide dynamic range of lidar return amplitude is provided by forming a piecewise-1inear PMT amplitude response, measuring the dynode outputs[7] and selecting automatically a linearly operating channel. Selection of the channel and digitization of the analog signal are carried out by the processing unit, using type 1107 PB 3A high-speed analog-to-digital converters. The information from the ADS outputs is appended to the number of the active channel and is stored in a high-speed buffer memory with 128 nine-bit words. The first data word from the signal processing unit bears information about the emitted pulse power. In the time between two successive sounding pulses, the data from the buffer memory is read into the microprocessor memory. The processing unit making it possible to delay triggering the digitization and to change the ADC sampling rate in real time so as to more carefully analyze a selected segment along the propagation path.

The system may contain, depending on the problems under consideration, from two to six receiving modules, four of which can be packaged with the transmitter module; the other two receivers are external and are used to determine atmospheric transmission along slant paths.

3. The phase measurement system consists of two receiving modules and an optomechanical unit. By means of an optical cable, the sounding radiation from the transmitter is introduced into the optomechanical unit, where it is split into six channels and fed to delay lines made of low-loss optical fiber. From the delay lines, the radiation is directed through collimators onto the object under study, at various angles to the axis of the photoreceiver. To increase phase-measurement angular resolution, it is possible to turn the optomechanical unit relative to the photoreceiver in 1° steps. The results of the scattering phase function measurements are processed by a built-in controller, and are then sent to the central processor or to the printer. The instrument is functionally connected to the "SPEKTR-3-AC"[8] aerosol particle-size analyzer, which makes it possible to monitor the spectrum of aerosol particle size while simultaneously measuring the aerosol scattering phase function.

The measurement system described above makes it possible to measure simultaneously:

a) lidar return signals at a maximum sampling rate of 100 MHz, with relative measurement error ±5% at a sounding path length of up to 20 km, and with input dynamic range ~ 10^4;

b) phase measurement signals from the field obtained at 6 scattering angles with dynamic range also ~ 10^4;

c) sizes of par-tides in 0.2–40 μm range and number densities of aerosol particles up to 15×10^3 cm^{-3} in a local volume, mass density, and visibility;

d) signals received from remote photodetectors at a distance up to 1.5 km, with input dynamic range ~ 10^4.

All of the measurements are carried out automatically with the built-in microprocessors. Overall system control, data collection and processing are performed by the central microcomputer.

A block diagram of the automatic data processing system is shown in the figure. The input of preliminary information into peripheral devices and the collection of information obtained in the process of measurement are accomplished with the help of the central micro-computer. To do this, a system applications program is loaded into the central microcomputer before beginning work.

The program consists of

a) a routine to handle lidar return signals;

b) a routine for phase measurements signal processing;

c) a routine to process the data obtained by the particle size analyzer;

d) a routine to process the signals received from external photodetectors.

The routine to process the lidar return signals contains the following Information:

1. Sampling rate of the analog-to-digital converters.
2. Delay time of ADC triggering.
3. Number of pulses per measurement.
4. Frequency of laser radiation.
5. Number of measurements.
6. Period of measurements.
7. Table of various coefficients necessary for signal restoration.

Following startup, this information from the central microcomputer is read into the microprocessor module of the lidar. During operation, the sampling rate and trigger delay are read into the lidar signal processing unit. The signal processing system enables one to sample lidar returns at 100 MHz, 50 MHz, 25 MHz, and 6.25 MHz. By delaying the ADC trigger, one can make measurements from 12 m to 20 km in steps of 189 m. The maximum number of pulses available per measurement is 32, at a maximum repetition rate of up to 30 Hz. The number of measurements is effectively unlimited. The system makes it possible to process two signals simultaneously, and to measure lidar returns at two wavelengths.

The phase processing routine contains the following information:

1. Table of coefficients necessary for restoring the signals.
2. Information on scattering angles.
3. Number of measurements.
4. Number of pulses.

The particle size analysis program contains:

1. Information about the time of measurement, the flow speed of the medium, the counting volume cross section.
2. An algorithm for calculating the microparticle number density in a local volume.
3. An algorithm for calculating the moments of the particle size distribution.
4. An algorithm for calculating the mass density and visibility.

Data on microparticle sizes is accumulated in the spectrometer microprocessor module. The module chooses the measurement regime (background monitoring, PMT dark-current monitoring), and also the time of measurement. Upon request from the microcomputer, information about the particle size spectrum is sent to the central processor. The calculation of the above parameters and their correlation with the phase data improve the accuracy and reliability of the data obtained.

The program for external photodetectors contains:

1. Trigger delays of the ADCs.
2. Initial data on photodetector placement.
3. Number of pulses per measurement.

4. Table of coefficients necessary to restore the signal.

5. Number of measurements.

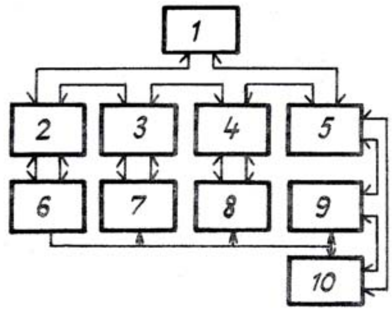

FIG. 1. Block diagram of the PIKHTA automatic signal processing system.
1 *is the central microcomputer;*
2 *is the lidar microprocessor module;*
3 *is the spectrometer microprocessor modal;*
4 *is the phase measurement microprocessor module;*
5 *is the microprocessor module for external photodetectors;*
6 *is the lidar return processing system;*
7 *is the spectrometer processing system;*
8 *is the phase measurement processing system;*
9 *is thwe processing system for external photodetector 1;*
10 *is the processing system for external protodetector 2.*

After transferring all the above information from the central microcomputer, operational system control is transferred to the lidar microprocessor module. Synchronization of system operation is accomplished by the lidar signal processing unit. The laser is triggered by commands from the lidar microprocessor module. The sync pulse from the laser triggers all of the signal processing systems. The measured data is read from the processing systems into the microprocessor modules, whereupon the next measurement is made. After finishing a cycle of measurements, the data from the peripheral microprocessor modules are read into the central microcomputer, which performs the data processing.

Thus, our proposed design principles, based on the authors' experience of building and running stand-alone[7,8] and proven by the development of the multipurpose "PIKHTA" system, lay the foundation for a transition to the design and use in atmospheric investigations of integrated sensor systems, which are designed to facilitate measurements of optical and physical parameters of the atmosphere that are much more informative, accurate, and reliable than those derived from stand-alone sensors.

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