AUTOMATED NEPHELOMETER OF OPEN TYPE FOR ATMOSPHERIC STUDIES

A.P. Rostov and I.A. Razenkov

Institute of Atmospheric Optics,
Siberian Branch of the Russian Academy of Sciences, Tomsk
Received December 27, 1996

Intellectual nephelometers of open type designed by the authors for in situ studies of the atmosphere are described. The nephelometers operate in near IR wavelength range. The construction and concept of the devices allow them either to work independently during several hours or to be operated remotely at a distance up to 500 m *from the central host computer.*

Nephelometers are widely used in investigations of atmospheric aerosol and for the air purity control.[1,2,3] Two kinds of automated nephelometers of open type were designed at the Laboratory of Atmospheric Turbulence of the Institute of Atmospheric Optics for carrying out atmospheric investigations, in particular, for the study of interaction between the turbulent momentum fluxes, fluxes of heat, and aerosol particles. The first one operates at two angles and is capable of recording the scattering signal at 45 and 170 degree angles. The second nephelometer was specially designed to be installed on a deltaplan. It receives the radiation only at the angle of 45°.

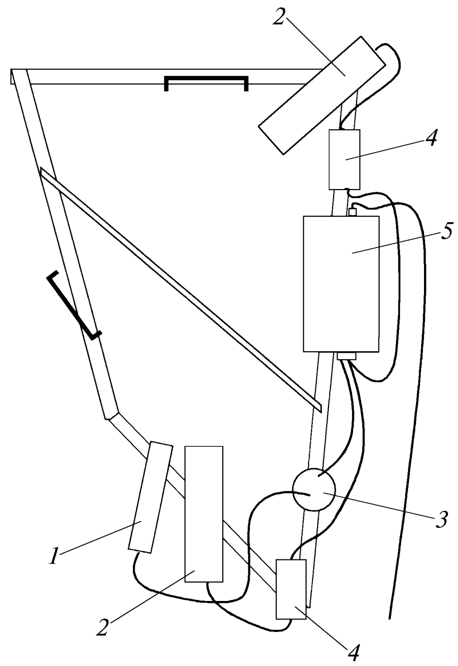

FIG. 1. Two-angle nephelometer of open type. 1) transmitter; 2) receiver of the scattered radiation; 3) power supply block of the transmitter; 4) power supply block of the receiver; 5) microcontroller and a modem.

The block-diagram of the first nephelometer is shown in Fig. 1. The device has high sensitivity and operation rate that allows one to record the scattered radiation at a rate up to 10 Hz. The receiving channel has the dynamic range of 100 dB. The device itself fulfils the requirements stated by on of the authors of this paper for a new standard for remote devices operated in a computer network whose length can reach 500 m.

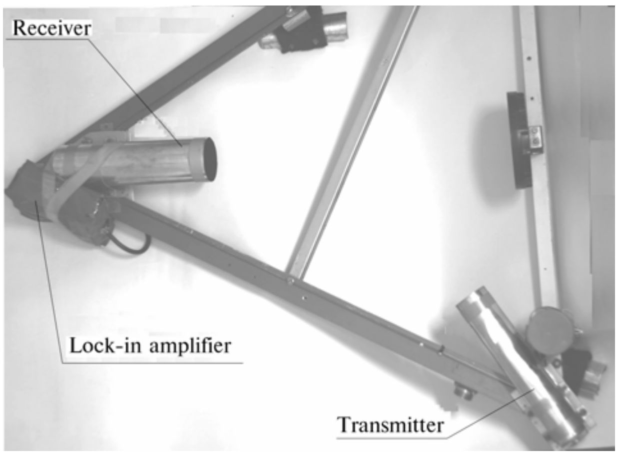

FIG. 2. The view of the onboard one-angle nephelometer of open type.

The view of the second device is shown in Fig. 2. It has a two times lower sensitivity at the same dynamic range and is aimed at recording scattered radiation, including that in clouds, at a rate of 1 Hz. The nephelometer operates under the control of the onboard recording complex.[5]

Both nephelometers record scattered radiation at the angle of 45° that was selected based on the fact that it is the radiation that has the maximum correlation with the total scattering coefficient.[6]

Both devices are mounted on a light rigid frame made of duraluminium. The middle part of the devices is open, that allows their operation in any position and

0235-6880/97/08 587-04 $02.00

makes them most appropriate for *in situ* operation conditions. The receivers and transmitters of the nephelometers are lens equipped with elongated blends which simultaneously are the protection housings. A black screen is placed in front of each receiver to decrease the interference of the background light. The compact electronic blocks of the transmitter, receiver and microcontroller with a modem (the first kind of the nephelometer) are mounted here on the device frame (see Figs. 1 and 2).

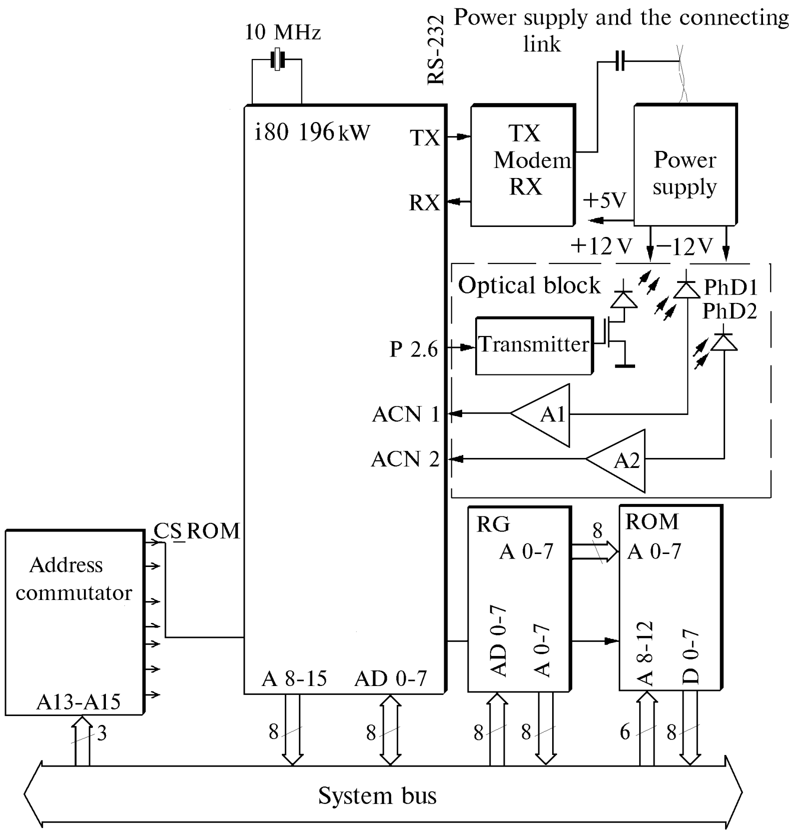

FIG. 3. Structure diagram of the nephelometer shown in Fig. 1.

The first nephelometer has the hardware-software structure. Its structure diagram is shown in Fig. 3. The principal control and record unit of this nephelometer is the i80C196KB microcontroller.[4] The controller has a 16-bit processor, 8-channel 10-bit analog-to-digital converter, two 16-bit timers, up to 5 parallel ports, series port, controller of the interruptions, and several ports providing the data output in the analog form.

The software of the nephelometer serves three modes of operation. The first, (the main), controls the functional units of the device, such as the change of the transmitter operation regimes, receiving and output of the data. The second supports the dialog with a user through the modem via power supply line. In this mode one can start the test programs and change the operational constants of the device. The third mode of the nephelometer operation is for making tests and allows to one examine the operation ability of all units of the device.

Let us consider in a more detail the hardware-software functioning of the onboard nephelometer operation. Since the built-in power supply has the energy limit (2.5 A·hours), the pulse-packed mode of operation is used. The energy necessary for the work of the transmitter, is stored in a capacitor of big capacity (68000 μF).

On a command from the processor, the KMOP key yields 20 pulses of current into the photodiode of the transmitter. The current amplitude reaches 1.5 A. The wavelength of the radiation is 0.87 μm. A portion of the scattered radiation comes to the receiver situated at the angle of 45° to the transmitter axis. An IR photodiode is used as a receiver. The electric signal from it comes to a preamplifier of the alternating current, which has the amplification coefficient approximately 3000 at the operational frequency. Then the signal comes to a lock-in amplifier with the transmittance band of the order of 100 Hz. Its amplification coefficient in the transmission band is about 10, and the total amplification coefficient of the channel is 30000. Taking into account that the total noise level of the photodiode and of the preamplifier reduced to the input noise is about 5 nV/Hz, and the noise level at the output of the entire channel in the working band is 0.02 V that corresponds to the microcontroller ADC codes value 4 – 6. On the whole, the sensitivity of the nephelometer is quite high.

The processor has time to make 180 readings from the power portion received, to square them and to sum. After finishing the measurement, the sum obtained is written to the 4-byte variable of the output bulk of data. The time of one measurement cycle of the nephelometer is about 18 msec.

The exact calibration measurements of the nephelometer were not carried out, but the following fact was observed many times. The nephelometer was situated in a room of the institute, and linked to a computer. The device operated continuously at a rate of 2 Hz. The room was closed for night, and, in spite of the absence of people, the decrease of the aerosol quantity was stably observed, and the signal level in the morning was only two times greater then the dark noise of the receiving path. As the door was opened in the morning, the splash of the aerosol concentration to a level 3 – 4 times greater than that before opening the door was observed at this moment. The diurnal behavior of the scattering coefficient at the angle of 45° is shown in Fig. 4 as a confirmation. Let us note that all recorded values are plotted as black points, and the plot is the copy of the part of the image on the computer display. The points are so dense in number that they make a dark band. The average behavior of the coefficient is shown as a white line in the middle part. The moment of people appearance in the room is well seen in Fig. 4 as a sharp increase of the scattering signal. The mean value continuously increased during a day.

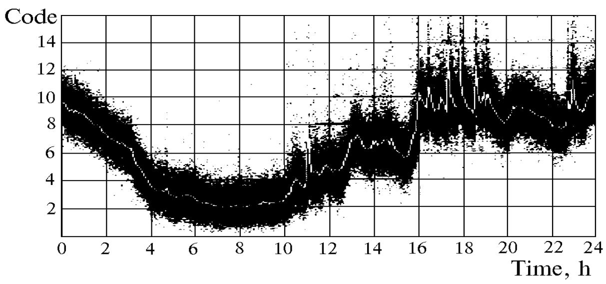

FIG. 4. Diurnal behavior of the scattering coefficient at the angle of 45° in the working room of the institute. The mean value is presented by the light curve.

The connection part of the program provides the operation of the nephelometer in the network of similar devices, that makes it possible to organize complex measurements of a lot of atmospheric parameters. The new device has parallel connection with a twisted pair of the connection line. The measurers included into the network react only on a 9-bit sendings, in which the number of the device we are interested in is transmitted. If the number of the device has coincided with the requested one, the device is linked with the connection line by the program, and the exchange of commands and data starts.

The linearity of the receiving channel of the nephelometer shown in Fig. 1 was examined in the room by means of the standard neutral light filters (NS-1 ... NS-12, State standard 9411-81). The filter transparency was calculated based on the filter thickness and the standard data (the data on the absorption index in the IR range were absent in the NS-filter certificates). The nephelometer readings were normalized to the value of the signal without a filter. Let us note that the reflection coefficient of the glass was not taken into account. The results of the examinations are shown in Fig. 5.

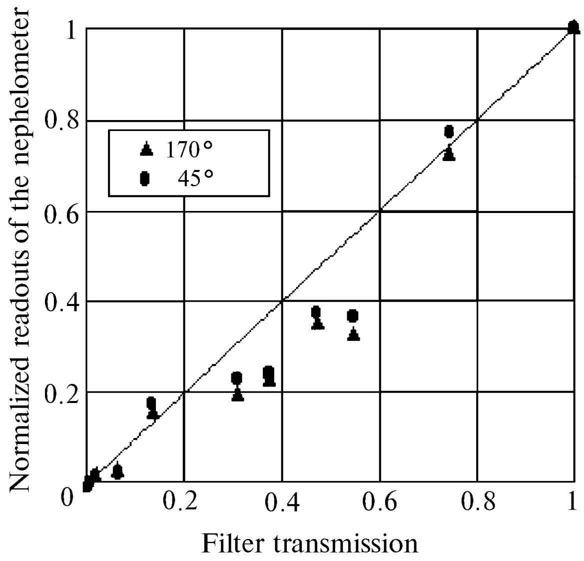

FIG. 5. Response of the nephelometer as a function of the input optical signal obtained by means of neutral optical glass (NS-filters).

The relative calibration of the devices was carried out by means of the milky scattering screen made of plexiglass that was placed in the same place on the special holder approximately in the middle at an angle of 67.5° to the transmitter and receiver axes. The NS-12 light filter with the transmittance of 0.000085 at the wavelength of 920 nm was placed in front of the transmitter. Let us note that the calibration values did not significantly change during several months before the field work. The device was not reconstructed, and its parameters were stable.

We used the nephelometers described above for the atmospheric investigations in summer and fall seasons of 1996. The onboard one-angle nephelometer was mounted on a motor air glider together with other instrumentation (radiometers, meteorological sensors). The work was carried out in the frameworks of the ARM Program (Atmospheric Radiation Measurements). The scattering coefficient (in relative units) was measured with the nephelometer up to 3 km.

The two-angle nephelometer (Fig. 1) was involved into a long-term campaign at Zarechny measurement site of the Institute of Atmospheric Optics near Tomsk. The nephelometer was mounted in the field on a 5 m-tall mast together with an acoustic meteorological station. Investigations were carried out in order to study the turbulent fluxes of heat and atmospheric particles in the near-ground layer. The diurnal behavior of the scattering coefficients at the angles of 45 and 170° is shown in Fig. 6.

The giant increase in the signal (see Fig. 6) was observed at night and in the morning. A little less maximum was observed at 2–3 pm. Without considering the details, one can note that the sensitivity and dynamic range of the nephelometer allows one to study the mean values as well as to record the pulsations of the scattering coefficient and to calculate its statistical characteristics.

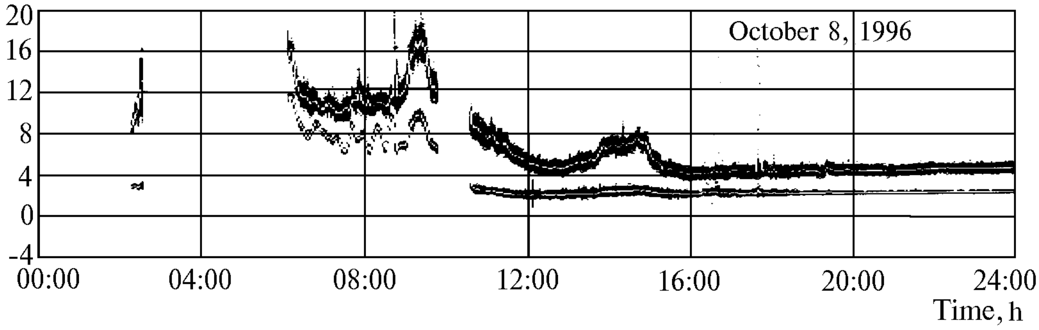

FIG. 6. Diurnal behavior of the scattering coefficient at the angles of 45 *and* 170°. *Measurements were carried out on October 8, 1996 in the field near Tomsk.*

One can relate the developed and constructed nephelometers to a new class of intellectual devices aimed at long-term operation in the atmosphere and capable of obtaining qualitative and quantitative data on the scattering coefficient *in situ*.

REFERENCES

1. N.E. Rityn' and V.P. Lazarev, Optiko-mekhanicheskaya promyshlennost', No. 2, 14–17 (1959).
2. M.V. Panchenko, V.I. Zhuravlev, N.I. Zhuravleva, et al., in: *Abstracts of Reports at the 7th All-Union Symposium on the Propagation of Laser Radiation in the Atmosphere*, Tomsk (1983), pp. 266–269.
3. M.V. Panchenko, M.V. Kabanov, and V.Ya. Fadeev, in: *Abstracts of Reports at the International Conference and School "Lasers and Their Application"*, Romania (1982), pp. 142–143.
4. *Microcontrollers of the MCS-196 Family* (Intel, 1995) pp. 126.
5. A.P. Rostov, Atmos. Oceanic Opt. **10**, No. 2, 132–137 (1997)
6. G.I. Gorchakov and M.A. Sviridenkov, Izv. Akad. Nauk SSSR, Fiz. Atmos. Okeana. **15**, No. 1, 53–59 (1979).