Software package for combined study of technogenic anomalies in the atmosphere

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Received March 13, 2006

The software package for a DAN-2 instrumentation complex intended for recording emission and absorption of optical and microwave radiation by gas and aerosol atmospheric emissions is described. The problem of automation of recording, storage, and processing of the experimental data has been solved. The following algorithms and methods are incorporated in the software for computation and estimation of the atmospheric anomalies: – computation of gas concentration in an industrial plume taking into account radiation extinction by gas and aerosol, the azimuth of the device sighting toward a source, and distributed illumination of the daytime sky; – computer simulation of the formation and distribution of the fields atmospheric emissions using various models (Gaussian, Berlyand, etc.); – forecasting of optical noises in the atmosphere taking into account different types of underlying surface and weather conditions; – reconstruction of the plume structure from its image. The modular principle used has enabled us to realize all the subsystems independently, so that each of them can be operated either independently or as a part of the software package. The software has a user-friendly graphic interface, high speed of mathematical calculations, and allows further extension and modifications of the calculation algorithms.

Introduction

The interaction of the atmosphere with the Earth's surface accompanied with natural and technogenic factors results in the formation of various gas anomalies in the atmosphere (halo of natural and industrial sources).[1] Optical properties of such anomalies differ from those of the natural atmosphere and can be used to detect gas and aerosol pollutions. The DAN-2 instrumentation complex has been developed at the Institute of Atmospheric Optics SB RAS to record emission and absorption of optical and microwave radiation, including those initiated by radioactive air contaminants. The complex allows one to perform express-monitoring of air pollution and remote detection of gas and aerosol industrial emissions, as well as to estimate radioactivity within an emission plume from the enterprises of the nuclear cycle and to forecast the state of radioactivity in the environment. It also provides computation and forecasting of the optical noises. Block-diagram of a DAN-2 model is shown in Fig. 1 (Ref. 2).

The DAN-2 complex includes the following instruments:

1) a correlation spectrometer, DAN-1,[3,4] to measure concentrations of CO_2, NO_2, and other gases;

2) a microwave spectroradiometer to record radiation at the frequency of 1420 MHz;[5]

3) a TV system for mapping the area of measurements and recording temperature anomalies.[6]

Measurements with the correlation spectrometer are based on isolation of a molecular absorption band against the background of overlapping lines and bands of other gases. The effect of single scattering by aerosol is taken into account in these measurements. This technique has been described in Refs. 3 and 7.

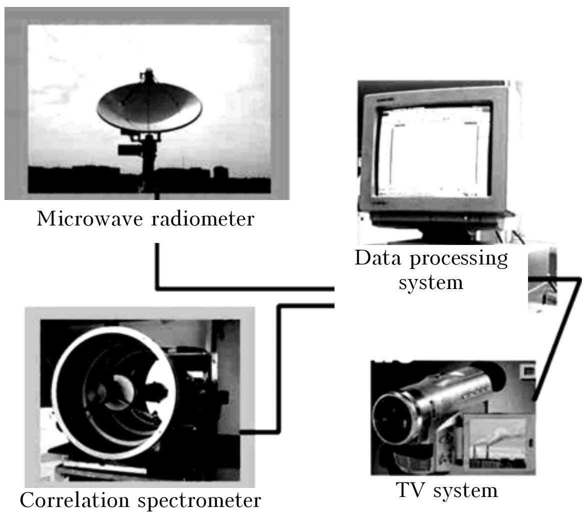


Fig. 1. Block-diagram of a DAN-2 model.

The microwave spectroradiometer uses the technique for a passive diagnostics of radioactivity in a plume by detecting the microwave emission from atomic hydrogen as an indicator of radioactivity in the plume.[8]

0235-6880/07/02 150-06 $02.00

This paper describes the software package, developed by the authors, which provides for acquiring the experimental data obtained with DAN-2, processing these data and images of the industrial plumes, computations of the parameters of atmospheric anomalies, estimation of optical noises in the atmosphere, and forecasting the dispersal of industrial contaminants.

Many software packages (SP) are used now in solving the environmental problems, but they are narrowly defined and not applicable to the tasks tackled using DAN-2. These packages can be conventionally divided into the following groups: the software for simulating radiation propagation in the atmosphere; the software for determining the main parameters of gas atmospheric components; software for image processing (e.g., LESSA, E-System, SAGDAM, etc.).

Processing DAN-2 experimental data is a complicated problem due to high rate of data acquisition, large bulks of experimental data, necessity of running experiments in real-time. Besides, to automate an experiment, it is necessary to know the experimental technique and take into account specific features of the data type and their processing. The quality and reliability of the processed data are to be taken into account as well, since the efficiency of the emergency control depends on them.

1. Components and structure of the software system for DAN-2 instrumentation complex

The block-diagram of the software system comprising separate programs is shown in Fig. 2.

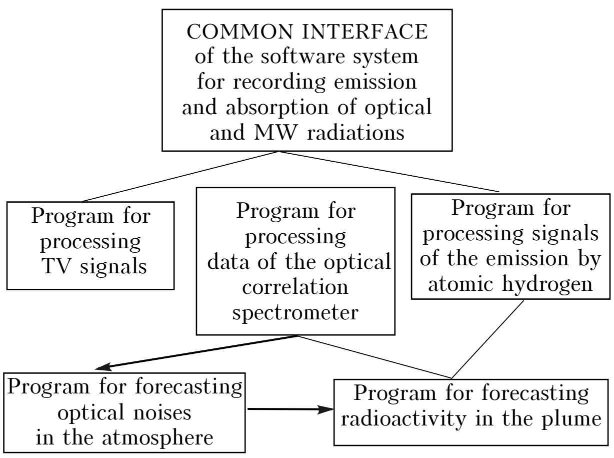


Fig. 2. Structure of the software system for DAN-2 instrumentation.

The software module needed is called from the common interface (see Fig. 3).

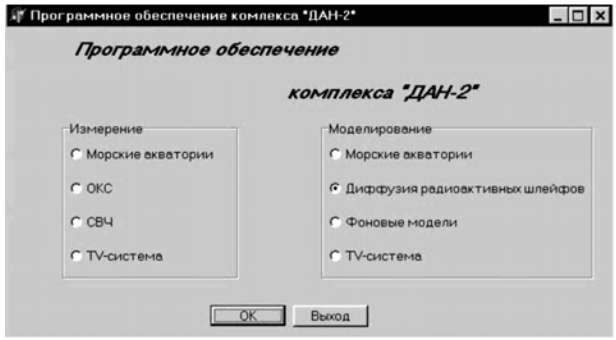


Fig. 3. Main menu of the DAN-2 software.

This software system is open, has the user-friendly WIMP interface allowing graphic representation of the computed results and access to data files, allows real-time computations (the “Measurement” module) and computation by a chosen model (the “Simulation” module), has high speed of mathematical calculations and enables further extension and change of calculation algorithms.

The DAN-2 software system is started with the loading **SYSTEM.EXE** module in the current directory; then the main menu appears where one can select the type of experiment.

Program for processing TV signals is used together with the BWF50-768/512-8 converter intended for conversion of video signals of black-and-white pulse, dynamic, or static CC1R TV images or the luminance part of composite color PAL TV images to their digital equivalents, their storage in the digital storage buffer (DSB) – video RAM of the converter, reading to the computer memory, and displaying a current or a stored image. The logic structure of this program is shown in Fig. 4.

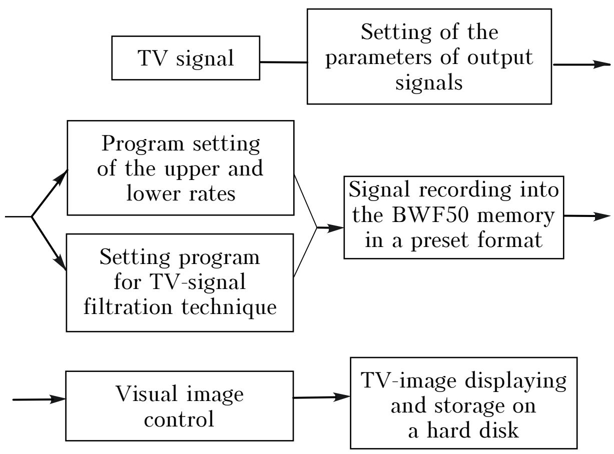


Fig. 4. Logic structure of “Processing program for TV signals”.

The input data for this processing program is a TV signal in a preset format. The synchronization signal at a video output repeats the shape of the signal at a video input. The output data of the program are

TV frames, transformed by filtering rates and method, in a preset format. The video output is the composite signal of 1 V in swing at the load of 75 Ω.

Program for processing data of the optical correlation spectrophotometer (OCS) is designed for recording two signals from an ADC-196-6 in a passive gas concentration meter. The program language is Turbo Basic (Fig. 5); there are some assembler routines. Two modifications of a remote pollution indicator operate in the near UV (0.3–0.4 μm) and IR (3–4.5 μm) spectral regions respectively.[7] The sounding range is up to 5000 m, the bulk concentration measurement range is $10^{-4}/D - 10^{-5}/D$, where D (m) is the plume diameter. Principal detectable gases are NO_2, NO, SO_2, J_2, H_2S, and CH_4. The "OCS" program controls measurements as well as processes and displays the data in real-time. Using this program, the dispersal of gas and aerosol emissions were estimated for various types of industrial anomalies in the near-ground atmosphere based on experimental data.[9]

Consider the program run in details. It includes 5 subprograms: for selection of the initial parameters, computation of the main parameters, computation of gas concentration, control of calculated results, and file-handling routine.

The subprogram for selection of the initial parameters allows one to chose a gas to measure (NO_2, CO_2, NO, O_3, CO, SO_2, etc.) and to set the initial parameters of an experiment (e.g., duration of a measurement, s; total operation time, min).

The subprogram for computation of the main parameters computes the background coefficient, caused by the sky brightness and the influence of an underlying surface as well as circuit noises, and the correlation coefficient between the background and signals.

The subprogram for gas concentration computation realizes two types of computations: in real-time according to the chosen direction and a type of concentration profile (horizontal or vertical) and with the regeneration of input and measured experimental data (the most recent one).

The subprogram for examination of the results computed allows one to present and review the obtained results in tabular and graphic forms and to print them out. *The file-handling routine* provides experimental data storage in ".dat" files format.

After starting the program module **OKS.EXE** that processes two input signals, i.e., the first one weakened by the plume halo and the second one weakened by the plume halo and a cell, the initial menu with the list of gases available for study is displayed (Fig. 6). Here one can also preset duration of measurements (in s) and total operation time (in min).

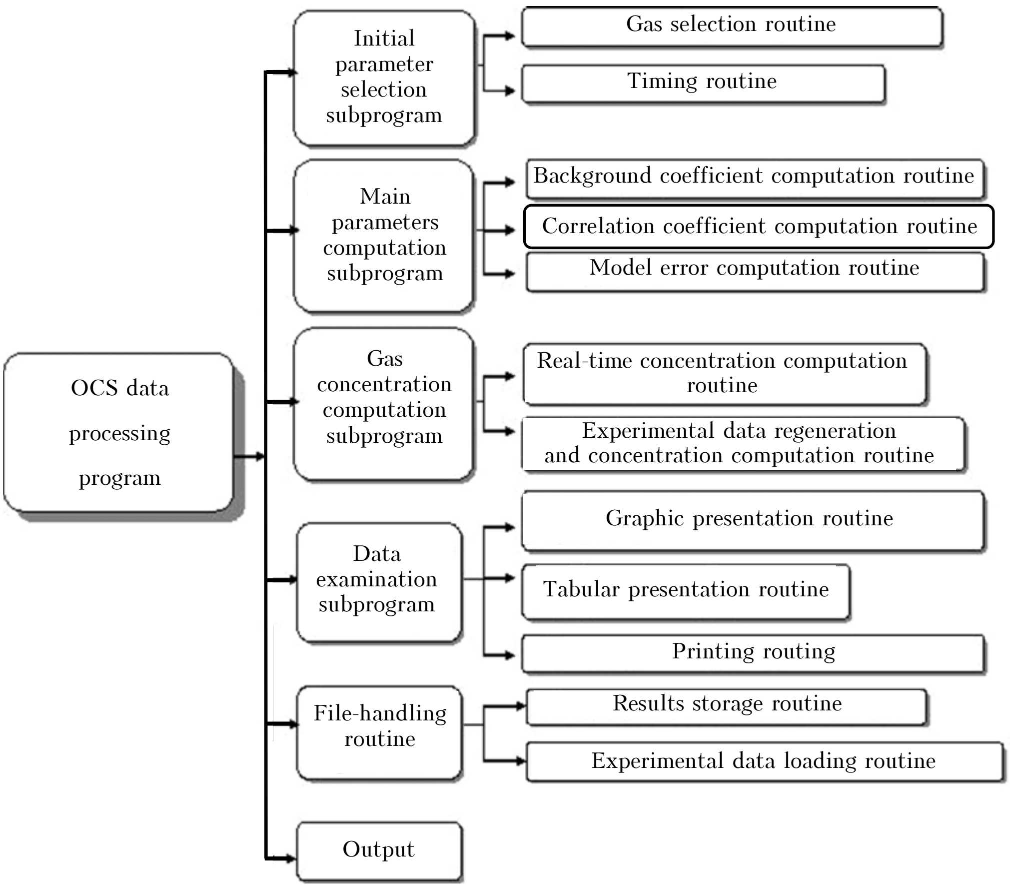


Fig. 5. Block-diagram of the OCS data processing program.

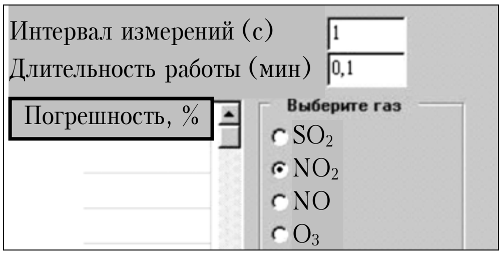


Fig. 6. A fragment of the menu for gas choice and input of the experimental parameters.

Further background measurements and calibration with the standard calibration cell are carried out (the action sequence is very important). After pressing the "Background measurement" menu key, the curves (Fig. 7) reflecting the signals obtained from two ADC channels are displayed as well as the numerical value of the background coefficient.

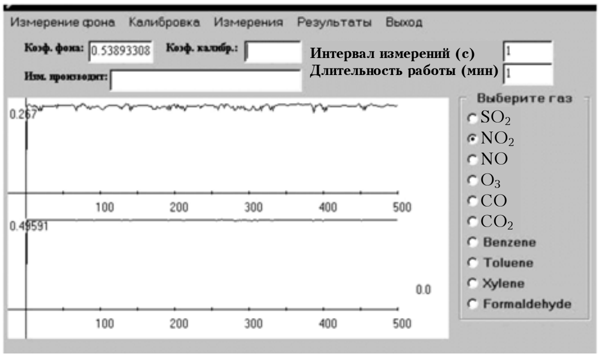


Fig. 7. "Background measurement" curves.

Then, the calibration with the given calibration cell is carried out. In so doing it is possible to enter the cell standard. As a result, the coefficient of calibration between the background and signal is computed. The software provides two types of measurements: data regeneration and computation ("Simulation" mode) and real-time computation ("Directional measurements") (see Fig. 8).

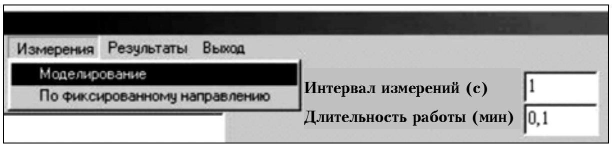
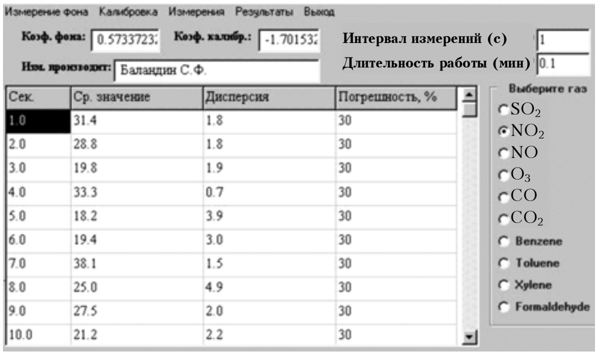


Fig. 8. Measurement type choice.

After choosing "Simulation" the file name is set where the data of the most recent experiment is stored. Then the program fills the fields of the initial parameters, background coefficients, calibration, and the table of results. Then further processing of the recovered data is possible.

If the "Directional measurements" is chosen, the real-time filling of the measurement table begins with the preset measurement duration maintained with the Windows internal clock. Upon the experiment completion, the table with filled fields is displayed: mean measured value, rms variance, instrumental error (an example is shown in Fig. 9).



Сек.	Ср. значение	Дисперсия	Погрешность, %
1.0	31.4	1.8	30
2.0	28.8	1.8	30
3.0	19.8	1.9	30
4.0	33.3	0.7	30
5.0	18.2	3.9	30
6.0	19.4	3.0	30
7.0	38.1	1.5	30
8.0	25.0	4.9	30
9.0	27.5	2.0	30
10.0	21.2	2.2	30

Fig. 9. The table of experimental values.

The type of data representation is specified in the "Results" menu (Fig. 10) where one can select tabular or graphic form or save them in a file.

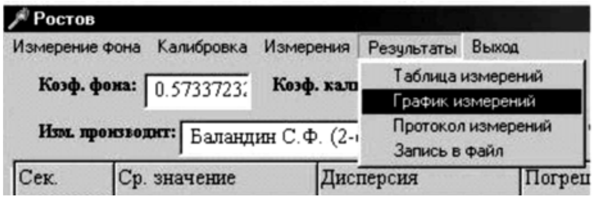


Fig. 10. Menu "Results" for choosing a type of the obtained data representation.

The "Measurement report" option allows one to print the experimental results out: the table of experimental values (see Fig. 9) and the plot (Fig. 11).

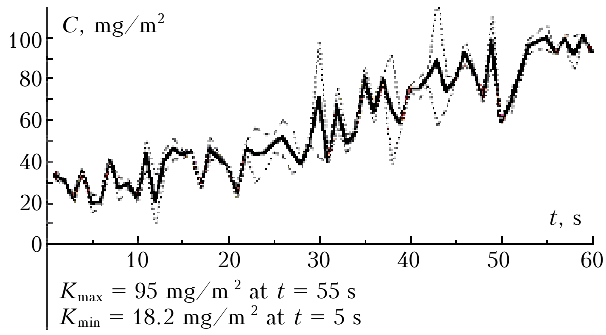


Fig. 11. Average NO_2 concentration C and the variance.

The program for processing the signals of atomic hydrogen emission provides the interface between the ADC via a specialized ISA modem, displaying the obtained data, filing data to the hard-disk, and processing all experimental data ended by creation of a data file. The logic structure of this program is shown in Fig. 12.

Input data for *the data acquisition module* are the flow of binary 12-bit numbers from the ADC; output data are binary numbers at 4096 2-byte numbers (16 files in 1 measurement with the 4-second measurement time).

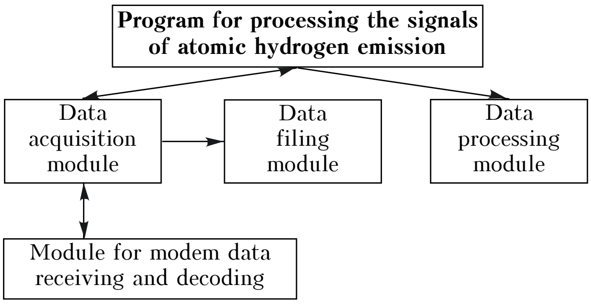


Fig. 12.

Input data for *the data processing module* are the set of files recorded by *the data acquisition module* during all the experiment together with the start and completion recording times. The recording time for every file is determined by the internal computer time and included in the filenames. The output data are files containing double-precise decimal numbers in the three-column form: time, intensity, and averaging error.

The program for forecasting the plume radioactivity is intended for computing the concentration distribution of an industrial air contaminant with the use of three models of contaminant dispersal from a source, i.e., Gaussian, Berlyand, and regional.[10,11] The program suggests the following services[9]:

– selection of a model from the above three ones;

– set the type of computations for every model;

– enter and correct input parameters for computation;

– selection of the initial parameters from a default table;

– link-up of other tables of input parameters;

– supplement and edit the lists of input parameters in the given tables;

– computation of the ground level contaminant concentration as well as contaminant concentration in a horizontal plane at an arbitrary height (for Gaussian and Berlyand models);

– computation of distribution of maximum contaminant concentration in the atmosphere (for Gaussian and Berlyand models);

– computation of the column contaminant concentration at an arbitrary distance from an emission source (for Gaussian and Berlyand models);

– computation of the contaminant concentration distribution along the dispersal trajectory with a time step (for the regional model);

– graphical representation of computed results (for all models);

– filing results, copying to the exchange buffer, printing out the computed results in the graphic form (for all models);

– plotting and scaling relative to the X-axis;

– computation of the maximum contaminant concentration, distance and height of its occurrence (for Gaussian and Berlyand models);

– tabulating the computed results (for the regional model);

– filing the table of computed results (for the regional model).

The program starts with the POLUTION.EXE module.

The program for forecasting optical noises in the atmosphere allows one to compute the level of noise illumination of the receiver from the natural sources of noise (scattered solar radiation, heat radiation of an underlying surface and the atmosphere).[12] To compute the parameters of optical signal propagation through the atmosphere, the data on zonal, seasonal, and diurnal variations of altitude profiles of parameters of absorbing gases, aerosols, clouds, meteorological parameters, parameters of turbulent air flows, especially in the near-ground atmosphere are needed. An integrated optical atmospheric model has been developed at the IAO SB RAS[13] based on the large bulk of experimental data, including vertical profiles of meteorological and optical parameters of the atmosphere is employed as the data bank for this program.

Conclusion

The software system has been realized based on the object-oriented programming environment Delphi and methods for computation, estimation, and forecast of the parameters of atmospheric anomalies. The use of the modular approach allows all subsystems to be realized independently with the possibility to work both independently and in the program complex. The DAN-2 data processing system has a user-friendly graphic interface, allows the computed results to be represented in the form of united scrolling tables or plots, provides the access to data files, has a high speed of mathematical calculations and can be extended, including the change of calculation algorithms. The system can be used to solve various problems of ecological monitoring of the atmosphere. It uses the WIMP-interface and could be useful for specialists with different levels of computer knowledge.

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