COMPUTER SYSTEM ALLOWING FOR ATMOSPHERIC EFFECTS ON POWER AND ACCURACY CHARACTERISTICS OF OPTICAL SYSTEMS

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Received June 1, 1993

A computer system designed for forecasting and on–line correction for the influence of the atmosphere on optical radiation characteristics is described. The main attention is paid to peculiarities of the system adaptation to IBM PC/AT.

INTRODUCTION

Development of modern aerospace geophysical investigations in the field of laser range finders, location, geodesy, and navigation is characterized by a wide application of active laser methods and technical means of automated monitoring.[1] All this stimulates interest of researchers engaged in the development of laser systems in operative prediction and accounting for the influence of the entire set of linear optical effects occurring in the atmosphere on the accuracy and power characteristics of opto–electronic systems.[2–3]

In this paper we describe a computer system which makes it possible to forecast and take into account the atmospheric effects on optical radiation characteristics. Much attention is paid to peculiarities of the system adaptation to a computer system. The algorithms used in this system can be found in Ref. 4.

1. FIELD OF APPLICATION

This system is a software intended for implementing the following functions: 1) computation of corrections for the range and refraction angle determined using laser and optical radiation of the visible and IR–ranges propagating in the atmosphere along slant and horizontal paths; 2) estimation of attenuation of radiation along the path; 3) determination of intensity of backscattered radiation collected with a receiving system; 4) estimation of the level of illumination of the receiving optics caused by natural sources of background noise that is spectral brightness of clear sky and thermal radiation from the underlying surface and the atmosphere; and, 5) calculation of statistical characteristics of optical beams caused by the influence of atmospheric turbulence.

2. OTHER KNOWN APPROACHES TO SOLUTION OF THIS PROBLEM

At the preceding stage of investigations into the grounding of the development of opto–electronic systems was based on some monographs.[5–12] The software packages developed for spectroscopy of absorption of atmospheric gases are applicable either to a wide–band radiation (LOWTRAN) or to more limited number of tasks connected with the attenuation of narrow–band radiation by molecular atmosphere (HITRAN, GEISA, LARA). There are no analogs of the software developed for the solution of the above–mentioned problems of atmospheric optics.

3. NOVELTY AND ADVANTAGES

This system is a set of applied programs which use the engineer techniques published earlier at the Institute of Atmospheric Optics[11,12] and based on new results of fundamental scientific investigations on atmospheric optics, carried out in the leading Russian institutes. This system involves the regional data banks summarizing the experimental and methodical material on atmospheric optics.

4. SPECIFIC FEATURES OF THE SYSTEM SOFTWARE

This computer system is developed on the basis of IBM PC/AT and consists of two subsystems: 1) subsystem of options of the operation mode and specification of input parameters and 2) subsystem of estimations of the power and accuracy characteristics of the specific optical systems.

The first subsystem is based on a DBMS "Clarion" and uses PASCAL language. This made it possible to provide the system with a flexible service (large number of color menu, help, and control) facilitating the work of a user who is not skilled in computer science. The option subsystem has four–level structure menu. The upper level is responsible for the common advertising of the system intentions and provides input into the system (Fig. 1).

The second level is the system menu which is responsible for the entering and correction of input parameters. At this level input parameters (path, locator, geoatmosphere, and model parameters) are to be put into special fields (Fig. 2).

This subsystem is equipped with three menu–blocks:

1. Option of the cycle parameters [F2].
2. Option of the model parameters [F3].
3. Option of the mode of operation of the system [F4].

The access to this menu is possible by a reset of the previous parameters of the path, locator, and geoatmosphere or by pressing the corresponding buttons <F2>, <F3>, or <F4>.

0235-6880/93/10 754-05 $02.00

COMPUTER SYSTEM FOR MAKING CORRECTIONS FOR THE INFLUENCE OF ATMOSPHERIC EFFECTS ON POWER AND ACCURACY CHARACTERISTICS OF OPTICAL SYSTEMS

This system makes it possible to estimate the following atmospheric parameters along slant and horizontal paths

Power characteristics	1. Molecular attenuation 2. Aerosol attenuation 3. Power of backscattering 4. Background noise
Accuracy characteristics	1. Regular refraction 2. Random refraction

[Entering the parameters of calculation]

[Quit]

FIG. 1. Menu of entering into the computer system.

The computer system is provided with the mode of computing of the given quantities when the input parameters of the path (height of locator, distance, observation angle, azimuth of the object, zenith angle, and azimuth of the sun) are changed in a cycle. Their start and end values and a step are set. Only one of these parameters can be changed after one computing cycle.

The model parameters are chosen in a separate menu (the third level) in which four parameters characterizing the atmospheric state along the path are given (Fig. 3).

These parameters, in their turn, are determined by the specific list of their permissible values (the fourth level, the third column, Fig. 3).

For creating a more correct model of the synoptical situation describing the real state of the atmosphere along the path it is necessary to specify the geographical location of the locator. This parameter has a distinct feature in the computer system. A color map of the Northern hemisphere corresponding to the chosen season with marked climatic zones and subzones on the screen (Fig. 4). It is necessary to choose the region of your locator location. The system is equipped with four main geographic zones: polar, midlatitude, arid, and tropical.

Entering the input parameters

Path

[F2 Cycle variable]	**Start**	**End**	**Step**
Height of locator	0.250	5.250	1.0 km
Distance	3.500	0.0	0.0 km
Observation angle	–23.0	0.0	0.0 degree
Azimuth of an object	123.0	0.0	0.0 degree
Zenith angle	45.0	0.0	0.0 degree
Azimuth of the sun	220.0	0.0	0.0 degree

Locator

Stationary locator No [Yes, No]

Aperture of radiator	5.0 cm	Angle of the source divergence	1.0 ang/min
Aperture of receiver	10.0 cm	Angle of the beam focusing	0.1 ang/min
Wavelength (main)	1.06 μm	Wavelength (additional)	10.6 μm
Angle of the field of vision	3.0 ang.min	Coherent source	Yes [Yes, No]

Geoatmosphere

Parameters to be measured

Nearby the surface:	temperature 293 K	Pressure 1014 Mbar	C_n^2 22.0·10^{-14}
Nearby the locator:	temperature 253 K	Pressure 529 Mbar	C_n^2 26.0·10^{-17}
Nearby the object:	temperature 250 K	Pressure 440 Mbar	C_n^2 14.0·10^{-17}

Height of the gauges 2.0 m Distance of the visibility 13.0 km [Surface] Grass, forest

[F1 Help] [F3 Options of the model parameters] [F4 Operation mode] Ctrl–Esc Quite

FIG. 2. The main menu for specification of the input parameters with their specific values for real experimental situation.

Model parameters	
Optical weather	Haze
Season	Summer
The time of the day	Afternoon
Zone number	2.2
Ctrl–Esc	Quite

Optical weather
Clear atmosphere
Haze
Misty haze
Mist + precipitation
Fog + precipitation

FIG. 3. Menu with the list of the model parameters and their specific values and menu of options of the typical situations of the optical weather.

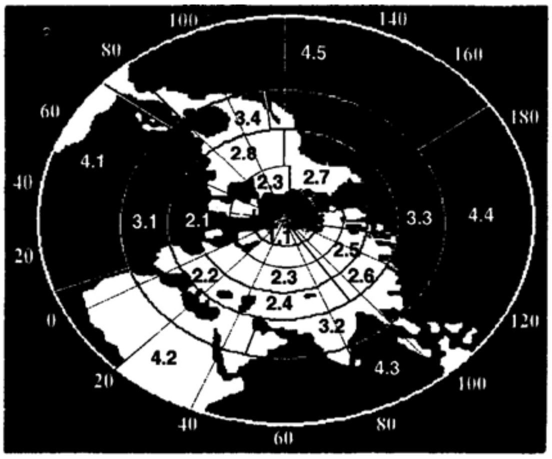

FIG. 4. The map of the Northern hemisphere of the Earth with geographic zones/subzones.

The computer system involves its own menu to choose the next five operation modes.

In the "Caclulation" mode, geoatmospheric parameters (T, P, C_n^2, meteorological visual range) can be set completely or partially, but as for the earth, it must be done obligatory. The undefined parameters are formed according to the model state along the path, which is close to the real situation and available data bank of the system.

Calculation by model
Calculation
Review of the results
Print the results
Quite

FIG. 5. Menu with the list of operation modes of the computer system.

The system provides making analysis of input quantities, their values control, and sound and text messages to aware a user in the cases of wrong combinations of the input parameters. For example: "Locator is under the earth surface!"

One of the advantages of this subsystem is the possibility of estimating of necessary characteristics in the "Calculation by model" mode under conditions of uncertainty of the geoatmospheric parameters.

A type of the underlying surface, entered via a separate menu, is obligatory at any computing modes in order to calculate background noise. If the calculation is assumed to be done in a cycle relative to any input parameter only the "Calculation by model" mode is used, because the geoatmospheric parameters are not set at each step of a cycle.

In the "Review of the results" mode it is possible to make analysis of the main parameters computed. The results may be presented either in the form of a unitary scrolling table that includes the main quantities resulting from all calculations carried out or in the form of complete tables for each variant of the computation (Fig. 6).

If it is necessary all calculated values and corresponding input parameters can be printed in the "Print the results" mode.

The computer system is equipped with a spectral support data as a reference source "Help". It contains the information about each field of the parameters and each menu including the first advertising menu (Fig. 7). You can call the reference source pressing the button <F1> when you are in the field of the input parameters or a menu. This reference source can be called to make clear the physical meaning of each parameter, using any form of their representation to look through the results.

5. THE SUBSYSTEM OF ESTIMATION OF POWER AND ACCURACY CHARACTERISTICS is a set of FORTRAN–77 programs located in the loading block which automatically starts to operate (from the subsystem of option of the operation mode) when the user enters into either the "Calculation" mode or the "Calculational by model" mode. The input data for this system are in the file formed by the subsystem of option of the operation mode. The computer system of the estimation has a module structure and consists of 30 subroutines of the total volume of 6000 strings. The result of its operation is the file which is transferred to the subsystem of option of the operation mode for its visual presentation in the form of the tables of calculated quantities.

6. CONCLUSION

The implementation of this computer system for the specific customer enabled us to substantially decrease the computation time necessary to account for the atmospheric effects both when designing laser stands and when operatively making corrections for the atmospheric distortions in the process of an operation of the system.

RESULTS OF CALCULATION								
H_{loc}	Dist.	Ang. (obs.)	Correction	Angle	Rel. angle	Backscat.	Atten.	Transm.
0.250	3.500	23.0	1.28	7.403	0.045	2.890E–10	1.04E–01	0.480
1.250	3.500	23.0	1.19	6.778	0.042	1.742E–10	7.45E–02	0.590
2.250	3.500	23.0	1.11	6.172	0.039	9.783E–11	4.77E–02	0.720
3.250	3.500	23.0	1.04	5.596	0.036	4.843E–11	1.53E–02	0.900
4.250	3.500	23.0	0.97	5,050	0.033	3.051E–11	7.89E–03	0.950
5.250	3.500	23.0	0.91	4.534	0.031	1.980E–11	4.76E–03	0.970
0.250	0.637	–23.0	0.17	1.518	0.008	3.093E–08	1.53E–01	0.820
1.250	3.197	–23.0	0.82	7.267	0.036	7.185E–10	1.15E–01	0.480
2.250	3.500	–23.0	0.82	7.410	0.037	4.753E–10	8.28E–02	0.560
3.250	3.500	–23.0	0.74	6.067	0.034	2.986E–10	5.95E–02	0.660
4.250	3.500	–23.0	0.67	6.353	0.032	2.296E–10	2.38E–02	0.850
5.250	3.500	–23.0	0.60	5.865	0.029	8.532E–11	9.34E–03	0.940

Result number 1

Height of locator 0.25 km, *Height of the object* 1.618 km, *Distance* 3.5 km
Observation angle 23.0 *Angle of the sun* 45.0 *Angle at the sun* 79.0

Nearby the surface	*Temperature* 293	*Pressure* 1014	C_n^2 $2.16\cdot10^{-13}$
Nearby the locator	*Temperature* 291	*Pressure* 984	C_n^2 $9.27\cdot10^{-15}$
Nearby the object	*Temperature* 282	*Pressure* 836	C_n^2 $1.74\cdot10^{-15}$

Correction for the measured distance: 1.28 m, *rms error of the correction* 0.09 m
The total transmission of the path: 0.4800
Efficient coefficient of the attenuation on the path: $1.04\cdot10^{-1}$ 1/km
Refraction angle: 7.403 sec of arc *rms error of refraction*: 2.85 ang.sec
Angle of the relative refraction 0.045 sec of arc *Additional wavelength* 10.6 μm
Spectral power of the background in the field of view: $9.67\cdot10^{-12}$ W
Pulse characteristic of backscattering: $2.89\cdot10^{-10}$
Angular rms deviation of the optical beam axis: $1.34\cdot10^{-10}$ sec
Angular rms deviation of the object image: $9.78\cdot10^{-1}$ sec

FIG. 6. An example of the results of a single computation cycle. The upper part of the table is the list of the input quantities; the lower part is the list of the results computed. The example of the scrolling table with the results of computed quantities where ***H_{loc}*** *is the height of a locator;* ***Dist.*** *is the distance to the object;* ***Angle (obs.)*** *is the angle of observation;* ***Correct.*** *is a correction for the measured distance;* ***Angle*** *is the refraction angle;* ***R. angle*** *is the angle of relative diffraction;* ***Backscat.*** *is the pulse characteristic of the backscattering;* ***Atten.*** *is the efficient coefficient of the attenuation along the path;* ***Transm.*** *is the total transmission along the path.*

Angle of the field of vision

This example characterizes a full angle of the field of view of the receiving optical system of a locator.

It is measured in minutes of arc and determined either through the diameter of the field diagram or through the diameter of the photoelectron detector.

This example is used in this system for computing the power of background radiation incident on the receiving window of photoelectron detector without taking into account the receiving channel transmission.

Minimum allowed value equals 0.1 min of arc.

FIG. 7. Example of the reference source for the specific parameter.

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