USE OF THE "SEAE" SOFTWARE PACKAGE FOR ESTIMATIONS OF THE OPTICAL SYSTEMS EFFICIENCY

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This paper reviews the applications of the software package "SEAEB developed for an efficient forecasting and taking into account the whole set of the linear optical effects on the accuracy and energy characteristics of lidar systems: i.e., correction for distance and refraction angle, attenuation of the optical radiation along a path, intensity of the radiation backscattered by the aperture of a receiving system, the value of illumination in the receiving channel caused by the natural noise sources, statistical characteristics of the optical beams caused by the effects of atmospheric turbulence.

INTRODUCTION

The modern aerospace investigations are characterized by a wide use of the laser and optical navigation devices, e.g. laser range finders, optical refractometers, the visible and infrared TV systems for the atmospheric monitoring, the systems for optical navigation, etc. The expert information systems used for launching missiles need for the data obtained by these devices. On the other hand, reliable work of the optical systems is provided by a real time information on the influence of the atmosphere on the accuracy and energy characteristics of opto-electronic devices.

This paper reviews some examples of applications of a new version of the software package "SEAEB[1,2] developed for a real time forecasting and taking into account the whole set of the linear optical phenomena effects on the accuracy and energy characteristics of lidar systems. The "SEAEB software has some advantages over the well-known program packages (LOWTRAN, HITRAN, GEISA, LARA) since it allows for various optical effects which can not be considered by the above listed programs.

The "SEAEB software allows one to calculate the following characteristics:

1) correction for the range and refraction angle for propagation of the visible and IR radiation through the atmosphere on the horizontal and slant paths;

2) attenuation of the optical radiation on the path (double path length);

3) intensity of the radiation backscattered by the aperture of a receiving system;

4) level of illumination in the receiving channel due to the natural noise sources (e.g., the scattered solar radiation, the heat radiation of the underlying surface and the atmosphere);

5) statistical characteristics of the optical beams caused by the turbulence effects.

Results of computations of the above mentioned parameters (taking into account the influence of the underlying surface and other factors) have been obtained for various types of the optical weather, geographical positions of a lidar, seasons, and time of day. The computations were based on models for various synoptic situations.

USE OF THE SOFTWARE PACKAGE FOR THE EFFICIENT ESTIMATIONS OF THE ACCURACY AND ENERGY CHARACTERISTICS OF LIDAR SYSTEMS

1. As to the range finders, the atmospheric refraction and changes of the velocity of a signal propagation along the path are known to result in errors of the derivation of actual angle and range from an object of interest.[5–8] Therefore, calculations of the correction for the range and refraction angle are considered to be very important for estimations of the atmospheric influence on the propagation of optical radiation.

Depending on the accuracy desired and efficiency of the refraction corrections, an approximate vertical profile for the refractive index or the meteorological parameters determining it, i.e., density, pressure, temperature, and the temperature gradient are specified by the user of the "SEAEB software. The setting of vertical profiles of the meteorological parameters for various seasons, time of day, the Earth climatic zones is provided in the computer interactive system in order to obtain more exact values of corrections for the distance and refraction angle. Algorithms for determining the correction for distance and refraction angle were developed taking into account the lidar location and the observation angle.

We have made calculations of the dependence of the correction for range and height of a lidar for a real

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weather situation: time of day – daytime, type of the optical weather – haze, observation angle – 20°, wavelength λ = 10.6 μm, visibility – 13 km. Figure 1 demonstrates quite a regular dependence of the correction of the measured distance on the initial input data. One has obtained a similar dependence of the angle correction on the distance and height of the lidar.

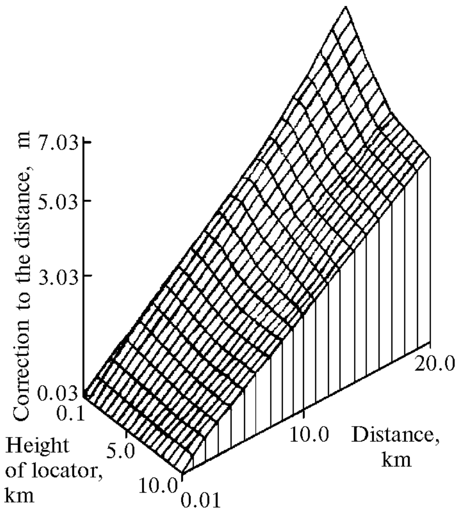

FIG. 1.

2. Estimations of the optical radiation attenuation due to the molecular absorption on slant and horizontal paths need the information on the meteorological parameters distribution. That is why, the dialogue options of "SEAEB allow the calculations of the altitude profile of the molecular attenuation coefficient as well as of the optical thickness depending on the wavelength, geographical zone, season and daily changes of the atmospheric meteorological parameters. The calculations involve a data bank on the profiles of pressure, temperature, humidity, and gas concentrations.[9,10]

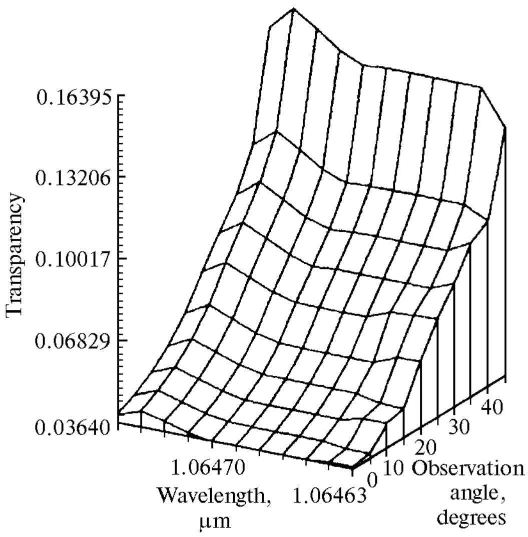

FIG. 2.

We have made the estimations of the atmospheric transparency (on the double path length) for the wavelengths ranging from 1.06463 to 1.06475 μm, with the observation angles from 0 to 45° (see Fig. 2). These calculations were made for the same synoptic situation as described in Paragraph 1. Figure 2 shows that the database used allows one to calculate the molecular absorption of laser radiation within the atmospheric transmission windows.

Results of modeling the average value of the attenuation coefficient along the path, for the same synoptic situation (as that presented in Fig. 2) and the wavelength interval, but at different parameters of the path, i.e., height of a lidar – 10 km, the observation angle from −30° to +45°, are shown in Fig. 3. The influence of the absorption spectrum fine structure on the attenuation of laser radiation is seen to result in a complicated wavelength and angular dependences of the attenuation coefficient.

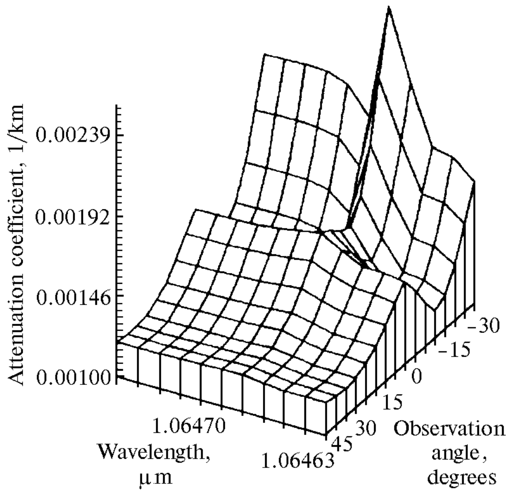

FIG. 3.

3. To calculate the intensity of the backscattered optical radiation incident on the receiving aperture, it is necessary to multiply the pulse transient function (hereafter PTF) by a pulse energy. The following expression is used for calculations of the time dependence of the PTF $I(t)$:

$$I(t) = c\, \beta_{\pi}(h)\, T_a/(2t^2)$$

(where $\beta = \pi$ is the scattering angle; t is the time of arrival of the scattered radiation; c is the speed of light; $\beta_{\pi}(h)$ is the volume backscattering coefficient at the altitude h; T_a is the transmission caused by the attenuation of radiation due to the aerosol and molecular scattering and absorption along the double path length. The wavelength and the observation angle dependences of the transmission T_a are shown in Fig. 2.

4. To obtain the maximum visibility range allowing the detection and recognition of objects, it is necessary to estimate the level of illumination of a

receiving channel due to natural sources of the noise and light, since background noises lead to a decrease both of the brightness contrast of an object and of a dynamic interval of the receiving channel. The background radiation sources depend on the solar coordinates, the observation directions, season, time of day, the geographical position, as well as on the parameters of a measuring device used.[11–13] The dialogue software “SEAEB allows the computations of the spectral brightness of a clear sky, thermal radiation of the underlying surface, and the intensity of illumination of the receiving system caused by the backscattered radiation.

Figure 4 demonstrates the distribution of the spectral intensity of a clear sky in the wavelength region of 1.06 μm for the following conditions: the “grass-forestB underlying surface, the azimuth of the Sun – 180°, the angular height of the Sun – 30° (i.e. zenith angle – 60°), the synoptic situation corresponds to that in Fig. 2. For computations of the spectral intensity of radiation incident on the receiving aperture, we used the following parameters: radius of the receiving aperture – 20 cm; field of view 2 min of arc; the observation angle and solar angle – not less than 15°; the angular distance from the observation point to the direction towards the Sun was not less than 5°. The accuracy of this estimation is 10%.

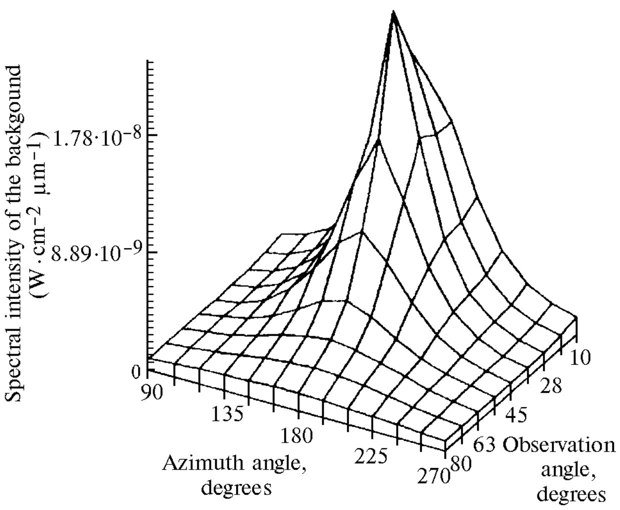

FIG. 4.

5. Statistical characteristics of the optical beam, propagating along slant paths, comprise the rms deviations of the beam propagation direction and rms deviations of the object image in the focal plane of the receiving optical system.

Dependence of the rms deviation of the optical beam axis on the observation angle and height of a lidar, for the same synoptic situation, is shown in Fig. 5. This figure shows that maximum of the atmospheric turbulence effects on the optical source beam is reached on the near surface paths.

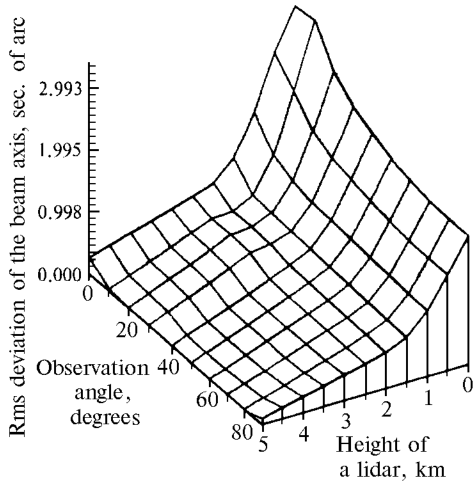

FIG. 5.

CONCLUSION

Using the software “SEAEB we have carried out an estimation of the accuracy and energy characteristics of a lidar (without details of its specifications) operating under real synoptic conditions. The software considered allows the efficient account for the atmospheric influence on the optical radiation propagation as well as to calculate some functional dependences like the above mentioned ones. The latter is very important for estimations of the efficiency of opto-electronic devices used for aerospace researches (e.g., telescopes, devices for optical navigation, etc.).

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