RESEARCH OF THE TRANSFERRING CHARACTERISTICS OF A SCANNING SPECTROPHOTOMETER

Zhivko Stoyanov Zhekov, Garo Hugassov Mardirossian, Petar Stefanov Getsov

Space Research Institute – Bulgarian Academy of Sciences 6, Moskovska St., 1000 Sofia, Bulgaria, phone: +359 986 16 83, e-mail: zhekovz@yahoo.com

When carrying out on-board or ground-based optical experiments in the field of space physics and remote sensing, it is very important to have information about the interference of the examined objects radiation with the surrounding medium and radiation diffusion in atmosphere and space.

When interfering with the surrounding medium, radiation becomes weaker and it changes. Radiation reflects and refracts at transiting from one environment into another. Refracted radiation diffuses itself and it refracts or is absorbed by the medium.

The relation between the emission which enters the medium, the radiation which is absorbed, the radiation which is refracted and the radiation which exits in the medium is the subject of the current research. Formulas are presented which characterize the optic diffusion of the radiation in atmosphere and space.

The carried out research can be applied in photometric and spectrophotometric calculation at the design stage of optic, electronic-optic and optic-electronic and laser devices for remote sensing which use absorption and lidar research methods.

Keywords: diffusion, radiation, space optical experiments

Radiation diffusion in the atmosphere depends on the interaction of radiation with the surrounding medium through which it passes and as a result radiation weakens and changes.

This influences remote sensing of the Earth, the research of other planets and research in the field of space physics [1,2].

When the radiation passes from one medium into another, it reflects and refracts. The refracted radiation spreads in a medium and at the same time it diffracts into small pieces into the medium or is absorbed by it. The correlation between the radiation entering the medium, the absorbed radiation, the diffused radiation and the transmitted one can be presented in the following way:

(1) $$\phi(\lambda) = \phi_\rho(\lambda) + \phi_n(\lambda) = \phi_\rho(\lambda) + \phi_{\alpha_\rho}(\lambda) + \phi_{\alpha_n}(\lambda) + \phi_\tau(\lambda)$$

Where: $\phi(\lambda)$ – monochromatic radiation which is on the borderline of two media;

$\phi_\rho(\lambda)$ – monochromatic radiation which is reflected by the borderline of two media;

$\phi_n(\lambda)$ – monochromatic radiation which entered into the medium as a result of refraction;

$\phi_{\alpha_\rho}(\lambda)$ – diffracted by the medium monochromatic radiation;

$\phi_{\alpha_n}(\lambda)$ – absorbed by the medium monochromatic radiation;

$\phi_\tau(\lambda)$ – monochromatic radiation that had passes through the medium.

By dividing the two parts of equation (1) by $\phi(\lambda)$, we obtain:

$$1 = \frac{\phi_\rho(\lambda)}{\phi(\lambda)} + \frac{\phi_{\alpha_\rho}(\lambda)}{\phi(\lambda)} + \frac{\phi_{\alpha_n}(\lambda)}{\phi(\lambda)} + \frac{\phi_\tau(\lambda)}{\phi(\lambda)}.$$

The following symbols are introduced:

$\frac{\phi_\rho(\lambda)}{\phi(\lambda)} = \rho(\lambda)$ a reflection coefficient of the monochromatic radiation from the medium;

$\frac{\phi_{\alpha_\rho}(\lambda)}{\phi(\lambda)} = \alpha_\rho(\lambda)$ a diffraction coefficient of the monochromatic radiation into the medium;

$\frac{\phi_{\alpha_n}(\lambda)}{\phi(\lambda)} = \alpha_n(\lambda)$ an absorption coefficient of the monochromatic radiation into the medium;

$\frac{\phi_\tau(\lambda)}{\phi(\lambda)} = \tau(\lambda)$ a transmission coefficient of the monochromatic radiation into the medium;

After substituting with the introduced symbols, we obtain:

$$\rho(\lambda) + \alpha_\rho(\lambda) + \alpha_n(\lambda) + \tau(\lambda) = 1 \tag{2}$$

The proposed coefficients are defined as spectral coefficients of reflection, diffusion, absorption and passing through. These coefficients show the amount of radiation reflected, diffused, absorbed and transmitted through the medium towards the radiation which has hit the borderline between the two media.

The amount of the radiation from the studied object which falls on the radiation receiver depends not only on the emitter's capacity but also on the characteristics of the medium through which this radiation spreads. The radiation's weakening in the middle is a subject of research to the monochromatic radiation.

A parallel beam of monochromatic radiation $\varphi(\lambda,o)$ passes through a homogeneous medium with width *l*. Supposing that pieces of the medium weaken the radiation, the change of its value can be presented in the following way, when the radiation passes through a medium with width dl:

$$d\phi(\lambda,l) = -\alpha(\lambda)\varphi(\lambda,l)dl, \tag{3}$$

where $\alpha(\lambda)$ is a coefficient of the weakening of the monochromatic radiation.

And

(4)
$$\frac{d\phi(\lambda,l)}{\phi(\lambda,l)} = -\alpha(\lambda)dl \,,$$

After integration, we get:

(5)
$$\varphi(\lambda,L) = \phi(\lambda,0)e^{-\alpha(\lambda)L} \,.$$

In this equation, the coefficient $\alpha(\lambda)$ characterizes the total weakening of the radiation due to the medium ingredients and this influences both the diffusion and the absorption and it is a sum of the corresponding coefficients.

(6)
$$\alpha(\lambda) = \alpha_\rho(\lambda) + \alpha_n(\lambda) \,.$$

If a complex beam radiation ϕ, which spectral distribution is characterized by the function $\phi(\lambda)$, enters into the medium, so on the basis of (4) and considering (5), the following can be presented:

(7)
$$\varphi(L,\lambda)d\lambda = \phi_0(\lambda)e^{-\alpha(\lambda)L}d\lambda \,.$$

If this equation is integrated by λ over the whole range of the researched specter, the amount of the complex radiation is defined at the medium exit.

(8)
$$\varphi = e^{-\alpha(\lambda)L}\int_{\lambda_1}^{\lambda_2}\phi(L,\lambda)d\lambda = \int_0^{\infty}\phi_0(\lambda)e^{-\alpha(\lambda)L}d\lambda \,.$$

For a certain narrow spectral interval the equation is

(9)
$$\varphi = e^{-\alpha(\lambda)L}\int_{\lambda_1}^{\lambda_2}\phi(L,\lambda)d\lambda = \phi' e^{-\alpha(\lambda)L} \,,$$

where ϕ and ϕ' are radiations at the entrance and at the exit of the medium respectively.

If we put $e^{-\alpha(\lambda)L} = \tau_1(\lambda)$, the equation (8) becomes

(10)
$$\varphi(\lambda,L) = \phi(\lambda,0)\tau_1^L(\lambda) \,,$$

or

(11)
$$\varphi = \phi'(\lambda,0)\tau_1(\lambda)^L \,,$$

The coefficient $\tau_1(\lambda)$ is a transmission coefficient of the radiation through a layer with a given length.

The transparency of the medium is characterized by the function of the spectral transmission $\tau(\lambda)$ for monochromatic radiation and the transmission coefficient τ for complex radiation.

The equations for defining $\tau(\lambda)$ and τ can be taken from equations (9) and (10).

(12)
$$\tau(\lambda) = \tau_1^L(\lambda) = \frac{\phi(\lambda)}{\phi_0(\lambda)} = \frac{\phi(\lambda, L)}{\phi(\lambda, 0)};$$

(13)
$$\tau = \tau_1^L = \frac{\phi(L)}{\phi(0)};$$

The following equation is valid for the total radiation weakening which is due to spectral medium transmission $\tau_\rho(\lambda)$ and the integral transmission τ_ρ when taking into account the losses from the diffusion and also $\tau_n(\lambda)$ and τ_n but taking into account the losses from the absorption:

(14)
$$\tau(\lambda) = \tau_\rho(\lambda)\tau_n(\lambda);$$

(15)
$$\tau = \tau_\rho \tau_n;$$

Every coefficient from equations (13) and (14) can characterize the transparency of the medium when taking into account the losses from diffusion or absorption by different medium components because each of these coefficients is a product of the type:

$$\tau_\rho(\lambda) = \tau_\rho(\lambda)_1 \tau_\rho(\lambda)_i \ldots \tau_\rho(\lambda)_k = \prod_{j=1}^{k} \tau_\rho(\lambda)_j;$$

$$\tau_n(\lambda) = \tau_n(\lambda)_1 \tau_n(\lambda)_i \ldots \tau_n(\lambda)_k = \prod_{i=1}^{n} \tau_n(\lambda)_i;$$

$$\tau_\rho = \tau_{\rho 1} \tau_{\rho 2} \ldots \tau_{\rho k} = \prod_{j=1}^{k} \tau_{\rho j};$$

$$\tau_n = \tau_{n1} \tau_{n2} \ldots \tau_{nn} = \prod_{i=1}^{n} \tau_{nn}.$$

Taking into consideration the last correlations, the equation defining the spectral transparency of the medium becomes:

(16)
$$\tau(\lambda) = \prod_{j=1}^{k} \tau_{\rho}(\lambda)_j \prod_{i=1}^{n} \tau_n(\lambda)_i \; ;$$

(17)
$$\tau = \prod_{j=1}^{k} \tau_{\rho_j} \prod_{i=1}^{n} \tau_{ni} \; ;$$

The given formulas are used when calculating the transmission coefficients of different optic media, including the atmosphere by means of the *Terma* Pulse Photometric Device from the board of the *Mir* Scientific Orbital Station. The *Terma* Device (Fig. 1) has the following technical characteristics:

Fig. 1

- spectral range of the integral channel; 200 – 630 nm.
- number of the narrow bands of spectral channels: 4.
- average width of the photometric channel: 2,5 ± 1 nm at level 0,5.
- basic objective is afocal with entrance hole of 82 mm.
- angles of the vision field of the objective: 15', 30', 1º, 2º.
- maximum sensitiveness of the device without interference filters is 10 R (relays) at wavelength 600 nm.
- passing coefficient of the interference filters: τ = 30 %
- time constant: 10^{-4} sec.
- dynamic range of measuring with the device: 2.10^5.
- pointing range of the device in the bearing: ±8º.
- moment of rotation of the device in the bearing: 100 g/sm.
- used electricity; $\leq$ 30 Wt.
- weight of the device without a container: 8 kg.
- dimensions of the device: 540 x 315 x 315 mm.

It can be concluded that the radiation spreading in the atmosphere is analyzed and formulas about monochromatic radiation are presented. The radiation amount is defined at the exit from the medium for a wide and for a narrow spectral interval.

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