ATMOSPHERIC ABSORPTION STRIPS' INFLUENCE ON OPTICAL PYROMETERS' WORK IN THE INFRARED SPECTRAL RANGE

*Jivko Zhekov, Garo Mardirossian, Angel Manev****,**
Kunyo Palazov, Ivan Hristov*

Space Research Institute – Bulgarian Academy of Sciences
www.space.bas.bg ; e-mail: office@space.bas.bg

** Solar-Terrestrial Influences Central Laboratory – Bulgarian Academy of Sciences*
www.stil.acad.bg; e-mail: palazov@mbox.digsys.bg

Abstract

There is a great interest in investigating the constant decrease of infrared radiation, which influences essentially general reduction in the atmospheric absorption strips. The atmospheric absorption strips are of great importance when solving important problems concerning ecology, defence and especially, space research.

The subject of the paper is detection of atmospheric strips' absorption, their influence on the operation conditions in pyrometers' work, the spectral strips located in the closer infrared spectral range.

The results prove the need to account for atmospheric gas absorption when working with pyrometers, sensitive in the infrared spectral range while observing distant objects of emanation.

There is a great interest in investigating the constant decrease of infrared radiation, which influences essentially general reduction in atmospheric absorption strips. Atmospheric absorption strips are of great importance when solving important problems concerning ecology, defence and especially, space research [1,3,4].

The need of a way to detect the existence of gas absorbing strips, constituting the atmosphere arises in measuring the temperature of distant objects with the help of a pyrometer - receiver of emanation, precise in the infrared optic spectral range. It is known [2] that the main absorbing components in the ground level of the atmosphere are water vapors and carbon gas. The correlation between them and their influence depend greatly on atmospheric conditions - humidity, temperature, quantity and composition of aerosols. Some strips - for example those in about 2.75 μm, 6.3 μm of H_2O and 2.7 μm, 4.3 μm, 5.2 μm of CO_2 and others decrease greatly their emanation even in normal atmospheric conditions.

The subject on the paper is detection of atmospheric strips' absorption, their influence on the operation conditions in pyrometers' work, the spectral strips located in the closer infrared spectral range.

In pyrometers' operation, a significant variation of ambient mean temperature is tolerated, t_a from + 5 … + 50 °C and relative humidity from 30 ... 80 %. The average concentration of CU_2 in the atmosphere is accepted in the borders 0,03 ... 0,04 %. The seasonal variations of CO_2 concentration in the ground level of the atmosphere are between 80 ... 90 % per year [5]. CO_2 concentration depends primarily on the place where the measurements are taken, whereas in industrial areas the variations of CO_2 might go beyond the above values. All this could lead to significant differences in received data, compared to real values, even with the use of an absolute black body model.

In order to eliminate the influence of atmospheric permeability, it is necessary to choose spectral intervals, in which there are no atmospheric absorption strips. In a number of cases, to ensure the necessary correlation between signal and noise, one should isolate sufficiently wide spectral intervals, within which atmospheric absorption strips fully or partially exist.

The operating permeability factor, $\tau_g(T)$ [7] is equal to:

$$\tau_g(T) = \frac{\int_{\lambda}^{\lambda+\Delta\lambda} \tau(\lambda, t_a)\xi(\lambda)\varepsilon(\lambda, T)b_0(\lambda, T)d\lambda}{\int_{\lambda}^{\lambda+\Delta\lambda} \xi(\lambda)\varepsilon(\lambda, T)b_0(\lambda, T)d\lambda} \quad , \qquad (1)$$

where: $b_0(\lambda, T)$ - spectral energetic luminance of an absolute black body with wavelength λ and temperature T;

$\xi(\lambda) = \tau_s(\lambda)S_\lambda$ - spectral transmitting function of the pyrometer;

$\tau_s(\lambda)$ - spectral characteristic of the light filter;

S_λ - spectral sensitivity of the emanation receiver;

$\tau(\lambda, t_a)$ - spectral atmospheric permeability factor at atmospheric temperature t_a;

$\varepsilon(\lambda, T)$ - spectral emanating ability of the investigated object.

It is worth minding that permeability alteration in the atmosphere influences the value of pyrometers' boundary effective wavelengths.

Having in mind the complex spectrum of water vapors and carbon gas's permeability, the object's temperature etc., it could be seen that the precise estimation of temperature alterations, at the time of variations of these values, requires enormous effort. An approximate calculation may be used for preliminary evaluation of the conditions accounting for such influence.

In [6], the average value of absorption $A = 1 - \tau$ in a certain frequency interval is presented. Au is a synonymous function of the effective quantity of water vapors along the path of beam l. The function determines the quantity of water vapors ω, which is measured in centimeters per layer of evaporated water.

$$\omega = ql(P_x + rP_a)^{2k} - \omega P^{2k}, \tag{2}$$

where: q - concentration in centimeters per layer of evaporated water, in kilometers per layer;

P_x - pressure of the absorbing gas;

P_a - atmospheric pressure;

r = 5; k = 0,4 for the place of water vapors' spectrums in the range between 1 ... 8,5 μm.

As shown in [6], the experimental data could be averaged by the formula:

$$A = 1 - \exp\left[-\left(\frac{\omega}{\omega_0}\right)\right], \qquad (0{,}05 < A < 1) \tag{3}$$

where: ω_0 - value, representing the effective quantity of water vapors, where A = 0,05 and depends on the wavelength.

We calculate the vapors' permeable spectrums of H_2O according to formula (3) for different values of ω (between 0,001 and 0,1 cm), characteristic of pyrometers' use and normal conditions (t_a = 20 °C). Since our task is to study the pyrometer's work at the ground level of the atmosphere, we could ignore the alteration of the pressure P, which is about 3 %, and in laboratory conditions, even less. The results are shown on Table 1.

Table 1.

Receiver of emanation	*ω*, cm	*T*, *κ*	τ_g
Germanium	0.001	1,200	0.98
	0.100	1,200	0.96
	0.100	1,200	0.83
Non-coolable PbSe	0.001	700	0.92
	0.010	700	0.74
	0.100	700	0.54
Germanium windows	0.001	500	0.93
	0.010	500	0.71
	0.100	500	0.46

Carbon gas absorbs in strips between 2.7 and 4.3 μm. When working with a pyrometer, it is necessary to account for these strips and the area of spectral sensitivity where the strips of Ge (Au), InSb, PbSe, Ge(Hg) and other types of emanation receivers are positioned.

The influence of CO_2 absorption strips could be eliminated, filtering these strips with the help of light filters (for example a cuvette filled with carbon gas). It is not possible to use cuvette with water vapors to determine the absorption strip of water vapors, because the vapors will condense on the cuvette's walls. This must be done with the help of special interferential filters or organic substances, possessing strips of absorption in these areas of the spectrum.

In conclusion it is worth noticing, that the results prove the need to account for atmospheric gas absorption when working with pyrometers, sensitive in the infrared spectral range while observing distant objects of emanation.

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