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On the Infrared Method of Monitoring Environmental Co_2 and H_2o Vapors

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Abstract: *Knowledge of atmospheric in the infrared (IR) waveband is essential in IR remote sensing at long distances, giving information on "Optical weather" conditions during field tests of thermal- vision equipment and other apparatus, as well as for the measurement of concentrations atmospheric CO_2 and H_2O vapor on the horizontal path. In ecological researches of a terrestrial atmosphere rather great value measurements of quantity water vapor and carbonic gas in an environment have. On the basis of the experimental data received on measurements of a spectral transparency of atmosphere in the wave lengths from 2.5 up to 5.5 µm where there are strong band of absorption water vapor (on 2.7 µm) and carbonic gas (on 4.3 µm) and with help of existing empirical dependences between a spectral transparency and quantity of absorbing molecules it is possible to determine concentration H_2O vapor and CO_2 on a site of measurements.*

Keywords: *CO_2 and H_2O vapor on the horizontal path; band of absorption water vapor (on 2.7 µm) and carbonic gas (on 4.3 µm); concentration H_2O vapor and CO_2 on a site of measurements; infrared spectral transparency of the atmosphere.*

1. Introduction

In ecological researches of a terrestrial atmosphere rather great value measurements of quantity water vapor and carbonic gas in an environment have. On the basis of the experimental data received on measurements of a spectral transparency of atmosphere in the wave lengths from 2.5 up to 5.5µm where there are strong band of absorption water vapor (on 2.7µm) and carbonic gas (on 4.3 µm), and with the help of existing empirical dependences between a spectral transparency and quantity of absorbing molecules it is possible to determine concentration $H\ _20$ vapor and $C0_2$ on a site of measurements. The present paper is devoted to representation of results and discussion of the given measurements infrared spectral transparency of the atmosphere. In the wave lengths region from 2.5 up to 5.5µm carried out with the help developed by us universal IR Spectral Radiometer "Sipan-A", in detail described in [1]. The conventional method of measurement of IR spectral transparency of atmosphere on the large distances is reception of a spectrum known IR source with externalmodulation of radiation when signals from a source are small incomparison with the contribution of radiation of a background. Advantage of this method consists that drift and fluctuations of radiation of a background do not influence final results of measurements. In work [1] techniques of power graduation of instrument, and also measurement methodology of point and extended IR sources are in detail analyzed. Corresponding relation for spectral calibration characteristic (k(λ)) of the Spectral Radiometer and interest of spectral contrast representing in this case for us point IR source are received by following relation:

$$W(\lambda)=\Delta S(\lambda)\bullet\omega\bullet I^2/k(\lambda)\bullet\tau(\lambda,l)A \quad (1)$$

Where, ΔS(λ) a difference between signals "source+background" and "background"; ω solid angle of the "Sipan-A" system (equal 3mrad); 1 - distance from a researched source up to instrument; τ(λ,l) spectral transparency of atmosphere on distance 1; the A - area of a radiating surface of a source.

2. Research Methods

We have carried out experiments in the middle latitudes of the European part of Russian, in summer. 1500m long horizontal path was selected. The measuring equipment included a standard black-body source (at a temperature 1270K), a chopper positioned in front of the source and IR Spectral Radiometer "Sipan-A". Structural diagram of experiment and measuring equipment is shown in Figure 1.

In this experiment, the internal reference source of "Sipan-A" system was not used, due to existence of the external source with chopper.

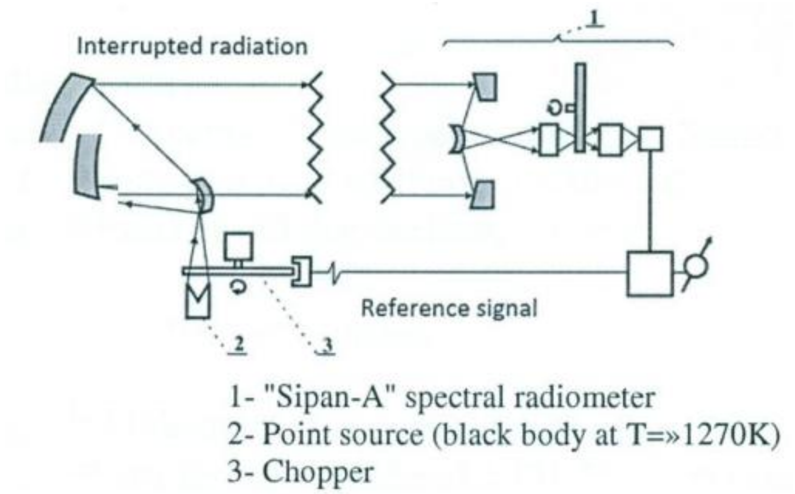

Fig1. *Structural diagram of dhe measurement equipment*

The system was synchronized by a radio signal transmitted from the source position and repeating the modulation half-periods. As results, the synchronous detector output was equal to a difference of signals "source + background" and "background". The same spectral measurements were repeated for a short path (200m). Using the brightness spectrum relations (1) for a point IR source we have obtained the spectral transparency of atmosphere τ(λ) at a distance 1500m. Averaged results over 30 spectral measurements are shown in Figure 2. Solid curves in Figure 2. correspond to calculated value [2], [8], while crosses show the results of our measurements. Simultaneously, meteorological parameter values were measured at the receiver site (humidity, pressure and temperature).

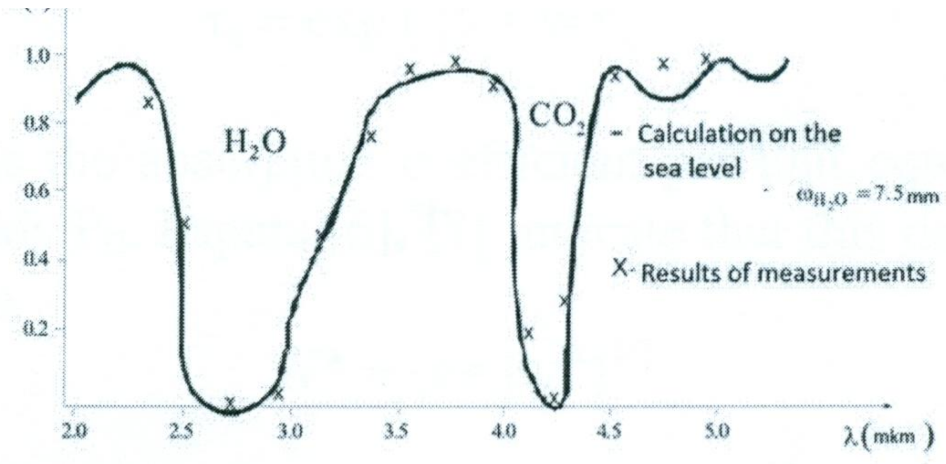

Fig2. *Spectral transparency of the atmosphere on a horizontal track length L=1500m.*

3. Results and Discussions

As a result of numerous experiments, Elder & Strong [3] have suggested the following empirical relation for water vapor absorption in narrow wavebands τ(λ), valid for horizontal paths at altitudes up to 3000m:

$$\tau(\lambda)=t_0 \bullet k \bullet \lg\omega_{H20} \quad (2)$$

Here ω_{H20} is the thickness of condensed vapor layer (cm), t_0 and k, are empirical constants for the considered λ [3]. Using the relation (2), with constants given in [3], as well as the results of our measurements, we have found the condensed layer thickness ω_{H20}= 4.5 and 9.5mm respecttively in the 1.9- 2.71 µm and 2.7-4.3µm wavebands. Thus the average value of ω_{H20} for a distance 1500m makes 7.0mm, which is close to the value 7.5mm obtained from in-situ measurement of meteorological parameters. The solid curve τ(λ) in Figure 2. was drawn for that very value (7.5mm). Multi-year theoretical and experimental researches by the group of authors [6], [7] has shown that atmospheric transparency in general is a function of the absorbent mass (condensed layer), effective pressure and wave number: $\tau = \tau(\omega, P_E, u)$. The effective pressure $P_E = P_N + B \cdot Pa$, where P_N is the line-broadening nitrogen pressure, B is self-broadening coefficient of the absorbing gas having pressure Pa (B=6 or 2 respectively for H_20 and $C0_2$). The same authors have shown that spectral transparency is well described by the relation

$$\tau_u = \exp(-\beta_0 \cdot W^*) \quad (3)$$

Where is the absorption coefficient per unit equivalent mass W*, which depends P_E. Papers [6], [7] indicate that this dependence may be taken in form

$$W^* = (\omega \cdot P_E^{\ 2k})^{1/2} \quad (4)$$

Where k and 1 are parameters depending on $\omega \cdot P_E$ and u, the values of which are given in [5]. For computation using the results of our experiments (in the 4.3 µm waveband of $C0_2$) it was convenient to introduce the equivalent masses separately for the center and peripheral parts of the waveband:

$$W_1^* = (\omega C0_2 \cdot P_E^{0,96}) \text{ (center) } \quad W_2^* = (\omega C0_2 \cdot P_E^{0,7})^{0,64} \text{ (periphery)} \quad (5)$$

W_1^*- was used in (2) when $W^* \leq 0.7$ and W_2^* otherwise

$$\tau_u = \exp(-\beta_{1u} \cdot W_1^*) \text{ (center) } \quad \tau_u = \exp(-\beta_2 u \cdot W_2^*) \text{ (periphery)} \quad (6)$$

The values of coefficients $-\beta_1 u$ and $-\beta_2 u$ are given in [5]. Effective pressure P_E in the relations (3)-(6) were expressed in atmospheres (~latm. at a see level), while min centimeters. $C0_2$ content in the 1500m long path was found from the relations (5) and (6) for the t_0 values measured in the 4.3µm waveband. The averaged value of $C0_2$ content was equal ω_{H20} = 4.2cm. Numerous researches dealt with $C0_2$ content in atmosphere, the results being given in the monograph [9]. Although there is a 6-fold difference between the minimum and maximum concentration of $C0_2$, one may assume it constant and equal to 0.03% in volume while calculating its IR absorption (large deviations from this value are extremely rare). Note that our calculated value of $C0_2$ volume concentration, equal to 0.028% stays in good agreement with the value obtained from multi- year investigations.

4. Conclusion

Received results of IR spectrometric measurements of atmospheric $C0_2$ and H_2 vapor can provide the significant information on structure of atmospheric gas pollution. The measurement methodology developed by us and the applied equipment represent an opportunity of carrying out of an operative estimation of the contents of different gases with the help pass**ive spectrometry in the wavebands from 3 up to 5µm and from 8 up to 14µm.**

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