ATMOSPHERE CONTINUUM ABSORPTION INVESTIGATION AT MM WAVES

E. A. Serov, M. A. Koshelev, V. V. Parshin, M. Yu. Tretyakov
Institute of Applied Physics Russian Academy of Science
Ulyanov Street 46, Nizhny Novgorod, 603950, Russia
Tel. +7 831 416 49 66, Fax +7 831 416 06 16, E-mail serov@appl.sci-nnov.ru

Introduction

Investigation of atmospheric gases spectral properties is demanded to develop absorption models. Such models are very important for the global Earth's atmosphere monitoring. Most of atmospheric lines and continuum spectral parameters are obtained in laboratory experiments. Recovered atmospheric parameters accuracy of depends directly on accuracy of laboratory measurements. Parameterization of the continuum absorption, in particular, the water vapor continuum is one of the most difficult problems. The problem is related to yet unknown physical origin of the continuum, its weakness in comparison with absorption in regular discrete lines of water molecule, and general difficulties of the water-related measurements.

The water-related continuum broadband measurement by the resonator spectrometer [1] revealed strong influence of water adsorbing on resonator elements on results of the continuum parameters measurements. Analysis [2] of the MM/SubMM continuum measurement methods used in the earlier studies leads to the conclusion that water adsorbing onto mirrors was a common factor influencing the water-related continuum parameters obtained in all well-known laboratory experiments. In all these cases gas cells with multiple reflections of radiation off inner mirrors were used as the most appropriate technique for weak continuum absorption investigation, although the problem of separation of water vapor absorption and absorption by water adsorbed on mirrors was not solved in the experiments. To overcome the problem it was proposed to use the cavity length variation method [1], which permits separation of these two types of absorptions and, as a result, the accuracy of continuum absorption measurements increases.

Setup and methods

The water-related continuum absorption measurements were carried out using the resonator spectrometer [3]. This instrument allows measurement of gas absorption in a frequency range 45 – 370 GHz with highest to date absorption variation sensitivity of about 4×10^{-9} cm^{-1}. The radiation source of the spectrometer is based on a backward wave oscillator (BWO) tube which radiation frequency is phase locked against a harmonic of the microwave synthesizer (Agilent E8257D). The BWO fast lock-in system permits precise digital frequency scanning in phase continuous regime.

A new modification of the resonator spectrometer was developed [2, 4] to apply the length variation method. Use of a module of two rigidly bounded maximum identical resonators differing in length by exactly a factor of two (Fig.1) allows accurate separation of the gas absorption and absorption by water adsorbed on the resonator elements. The module is placed in a chamber with temperature controlled between -30 and +60 °C, which permits investigation of temperature dependence of absorption. To control the stability of equilibrium conditions a set of temperature and humidity sensors is used through the cavity.

All cavity mirrors were manufactured at once using the same technology and materials. Coupling elements for both cavities were made of one 4 mkm thick Teflon film sheet (both film frames had the same orientation relative to the sheet) and were placed at 45° to the cavity axes at the same distance from the lower mirrors. An electromechanical switch blocks the electromagnetic field in one resonator and at the same time opens the other one. Thus, the excitation and the response recording for both resonators occur alternately.
The absorption coefficient in a mixture of pure N_2 with water vapor can be calculated [2] from measured resonance curve widths of two resonators of the module if we assume equality of the "wet" coupling and mirror loss in resonators:

$$\alpha = \frac{2\pi}{c}\cdot(2(\Delta f2 - \Delta f2_0) - \Delta f1 - \Delta f1_0)), \qquad (1)$$

where "*1*" and "*2*" corresponds to the short and long resonator, respectively, $\Delta f1,2_0$ is resonance curve widths of resonators, filled with dry nitrogen evaporated from the liquid phase.

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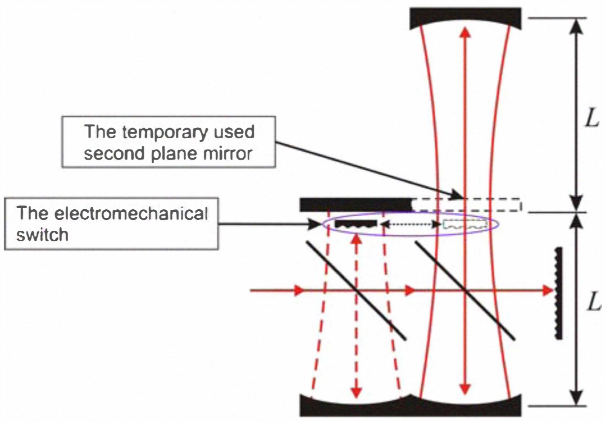

Fig.1. The scheme of two rigidly bounded resonators.

Test experiments

Before starting the continuum absorption measurements special test experiments were undertaken to measure water-related loss in two identical resonators of the same length with identical upper plane mirrors (Fig.1). Similar experiment, described in [2], revealed systematic discrepancy which was attributed to non identical coupling of the resonators. In new series of experiments in addition to the careful alignment of the coupling angles we also used more hydrophobic Teflon film for our coupling elements instead of PETP film. The discrepancy in water-related loss has significantly reduced. However, it was found that the discrepancy also depends on a particular part of the film used for the coupling element in each resonator. The most probable explanation is the film sheet heterogeneity. After several experiments the most appropriate combination of coupling elements was found. The discrepancy in water related loss of two identical resonators with these particular coupling elements was of the same order of magnitude as statistic error (Fig. 2).

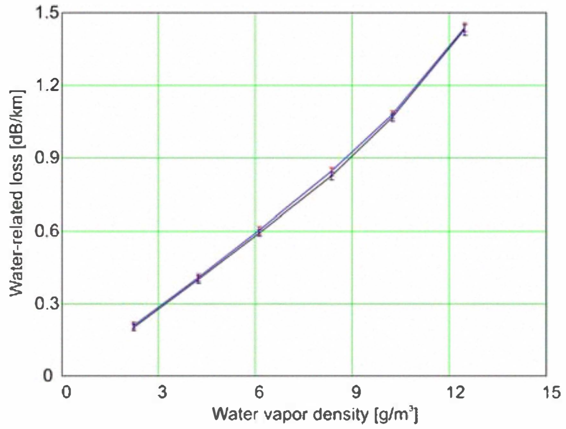

Fig.2 Water-related loss in two identical short resonators (L = 348.74mm) as a function of water vapor density. (T = 23.2^0 C, f = 124.78 GHz)

Water-vapor continuum measurements

First results of water-related continuum measurements obtained by the aforementioned method are presented. The absorption in a mixture of pure N_2 with water vapor was studied at 10 frequency points from 108.1 to 143.2 GHz at temperatures 25.4, 31.4 and 37.1^{0}C. The contribution of discrete water vapor lines was calculated as a sum of Van Vleck–Weisskopf profiles of most intense lines up to 1 THz (the line list from MPM98) using line strengths from HITRAN database. For the line broadenings we used where possible experimental data [5-7] or results of complex Robert-Bonamy calculations by Gamache [8]. After the contribution of discrete lines had been subtracted from the total absorption, the experimental data were fitted to the conventional empirical analytical representation of the continuum absorption [9]:

$$\alpha_{cont} = (C_{H_2O-N_2}(T) \cdot p_{N_2} + C_{H_2O-H_2O} \cdot p_{H_2O}(T)) \cdot p_{H_2O} \cdot f^2 \qquad (2)$$

Preliminary results of the fitting in comparison with earlier ones are given in the table below.

Table. Water-related continuum absorption coefficients in $\frac{dB/km}{GHz^2 \cdot hPa^2}$.

T, K	continuum parameters	Present work	Kuhn et al. [10]	MPM-92(*)	Ma, Tipping [11]
298.6	$C_{H_2O-N_2}$	$2.79(14)\cdot10^{-9}$	$3.07(8)\cdot10^{-9}$	$2.77\cdot10^{-9}$	$2.16\cdot10^{-9}$
	$C_{H_2O-H_2O}$	$8.5(6)\cdot10^{-8}$	$9.48(17)\cdot10^{-8}$	$8.1\cdot10^{-8}$	–
304.6	$C_{H_2O-N_2}$	$2.46(6)\cdot10^{-9}$	$2.81(8)\cdot10^{-9}$	$2.61\cdot10^{-9}$	$1.97\cdot10^{-9}$
	$C_{H_2O-H_2O}$	$7.1(2)\cdot10^{-8}$	$8.06(15)\cdot10^{-8}$	$6.98\cdot10^{-8}$	–
310.3	$C_{H_2O-N_2}$	$2.86(14)\cdot10^{-9}$	$2.59(8)\cdot10^{-9}$	$2.47\cdot10^{-9}$	$1.80\cdot10^{-9}$
	$C_{H_2O-H_2O}$	$5.0(3)\cdot10^{-8}$	$6.94(13)\cdot10^{-8}$	$6.07\cdot10^{-8}$	–

(*)Coefficient $C_{H_2O-N_2}$ is calculated by multiplying corresponding coefficient from MPM-92 by factor of 1.16. This factor was calculated using $C_{H_2O-N_2}$ and $C_{H_2O-O_2}$ coefficients ratio from [12].

These preliminary results are not in the contradiction with the earlier ones in whole. However, there is not enough information for the present moment to make the general conclusion.

Acknowledgments

This work is partly supported by the Russian President Grant MK-139.2010.2 and RFBR (Grants 09-05-00586a, 09-02-00053a).

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