Passive Microwave Mobile System for Atmospheric Boundary Layer Temperature Profilers and Total Water Vapour Content

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Abstract— This paper presents a new mobile microwave system for continuous measurements of atmospheric boundary layer thermodynamics. The main parts of the system are scanning 5 mm radiometer for atmospheric boundary layer temperature profile measurements, dual channel microwave radiometer for total water vapor content measurements, GPS receiver, meteostation and data system. Mobile system was successfully tested in September 2008 in the field expedition at mountains region.

1. INTRODUCTION

Permanent data about thermodynamic characteristics of atmospheric boundary layer (ABL) are necessary for a long range of investigations and applications, they are investigation of urban heat island, analysis of emissions of different gases in air, exploration of solar eclipse in atmosphere effect, perfection of short-range forecasts, prognosis of air-pollution spreading, danger meteorological occurrences prognosis and high-frequency propagation prognosis [1–3]. Since 1994 for continuous measurements of temperature profiles in ABL meteorological temperature profiler MTP-5 is widely used [1, 4]. Experience of applying MTP-5 showed that often required mobility of measurements, especially for urban heat island investigation, features of mountain thermal conditions [1]. Therefore in 2005–2006 was developed and produced mobile system for exploration temperature profiles in ABL which was used in both large cities and field scientific expeditions [1, 3]. New version of the microwave mobile system was created and tested in 2008 on the basis of off-highway car UAZ "Patriot" (Fig. 1). Basic difference of new mobile system is a presence of the channel for measurement of total water vapor content and using new direct-gain radiometer in the temperature profiler.

Figure 1: Mobile microwave system installed on UAZ "Patriot".

2. SYSTEM DESCRIPTION AND RESULTS OF TESTS

The mobile microwave radiometric system for investigations of thermodynamic characteristics includes a microwave temperature profiler installed in box protected from vibration and dust influence, two-channel microwave radiometer for measurements of total vapor content, navigation GPS

receiver, meteo-station, commutator, meteo-shell and a data receiving system based on mobile PC. Structural chart showed at the Fig. 2.

The meteorological temperature profiler MTP-5 used for measurements of temperature profiles of ABL [1–4]. The meteorological temperature profiler consists of scanning device, antenna system, microwave radiometer, analog-digital converter and control of scanning device board. Direct-gain microwave receiver is used in the temperature profiler. Rejection from superheterodyne scheme construction has allowed to increase sensitivity and to improve stability. This makes radiometer more reliable. Structural chart of temperature profiler showed at the Fig. 3. MTP-5 controlled from PC through analog-digital converter and control of scanning device board. Scanning process goes through 12 angles from horizon to zenith (0–90°). Antenna system consists of dual-mode horn feed fixed at a radiometer cabinet and rotating parabolic deflector.

Microwave radiometer consists of front waveguide made from thin-walled rust-resisting pipe which also serve as crossover from circular waveguide to rectangular waveguide. Front waveguide operates as thermo-coupling too. In a temperature-controlled unit located modulator (M), rectifying cell (RC), three high-frequency amplifiers (HAF) which assembled on basis CHA2159 chip, microwave filter, square detector (SqD), low-frequency amplifier (LFA), synchronous detector (SyncD), reference voltage generator (RVG).

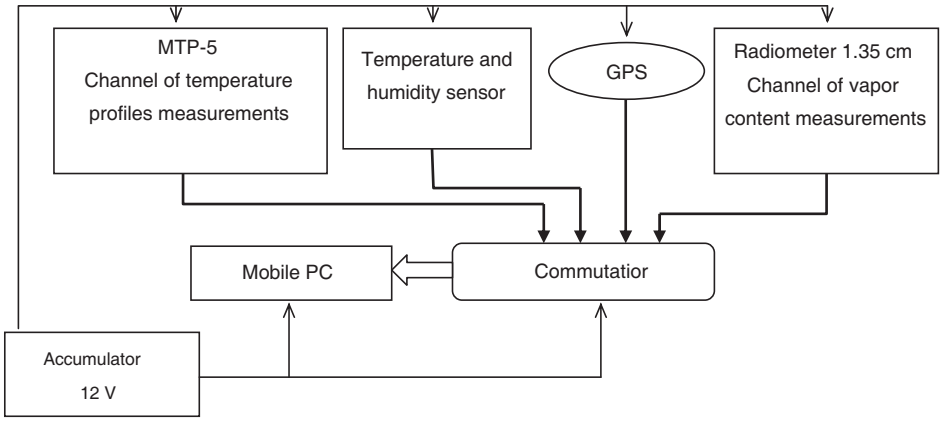

Figure 2: General structural chart of mobile microwave radiometric system.

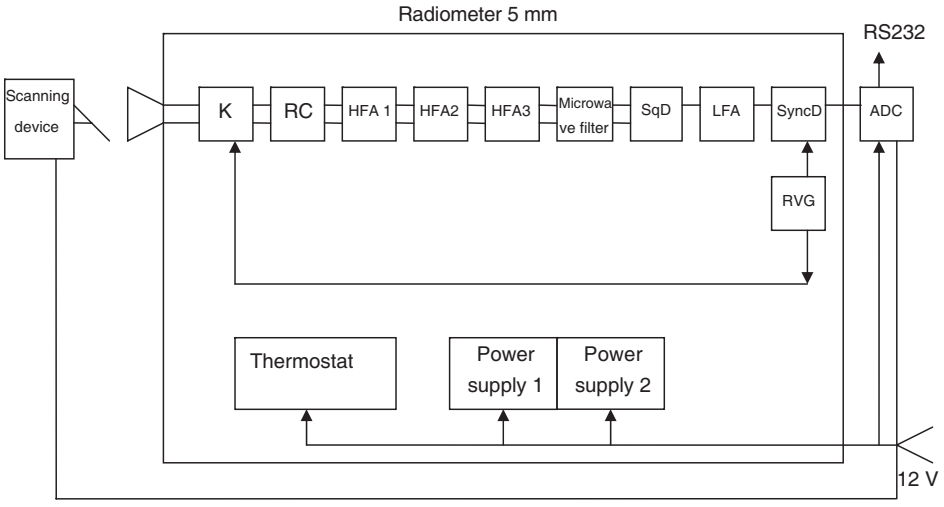

Figure 3: General structural chart of meteorological temperature profiler MTP-5.

Whole system placed in shell and powered from stabilized power supply by 12–15 Volt.

Microwave temperature profiler provides measurements of temperature in a range 0–600 meters with a step 50 meters every 5 minutes with inaccuracy 0.2–0.7°C twenty-four hours a day almost in any conditions.

Instrument for measurements of total vapor content in atmosphere constructed on a basis of 1.35 cm range radiometer. Channel for measurements of integral water content consist of receiving horn antenna, thermo-coupling, broadband circulator which used for dividing receiving channels by frequencies, filter 1 to $f \sim 22253$ MHz (Δf-400 MHz), filter 2 to $f \sim 25$ GHz (Δf-600–800 MHz), modulator, broadband circulator $\mathcal{N}$º. 2, wideband high-frequency amplifier, square detector with low-frequency amplifier and two synchronous detectors. Output of synchronous detector 1 give voltage v_1 analogical to receiver antenna temperature on frequency $f1$, output of synchronous detector 2 have voltage v_2 which analogical to temperature on frequency $f2$. Integral water content of atmosphere will proportional to difference of voltages $\Delta v = v_1 - v_2$. Utilization of this scheme allows to improve accuracy of measurements of total vapor content in atmosphere and to simplify calibration process. Comparisons with radiosondes showed that radiometer provides measurements of total vapor content with inaccuracy 0.2 g/cm^2.

Creation of movable system for investigations of thermodynamic parameters of atmosphere solves problem of moving all system to different locations for measurements. For accurate navigation and for height monitoring system includes GPS-receiver. In a record mode location data writing into measurements data files simplifying data processing. Temperature and humidity sensors included in the system for monitoring of surface layer parameters and also for MTP-5 profiler calibration.

Mobile microwave system was successfully tested in the expedition to Karachay-Cherkess Republic, Stavropol Krai in an area of Kislovodk city and also in a mountains on different heights.

3. CONCLUSION

In a range of modern meteorological devices appeared new distant system for monitoring thermodynamic characteristics of atmospheric boundary layer. Utilization of this system can be useful both for fundamental investigations of atmosphere and surface layer interaction and for carrying out a range of applied works.

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