MICROWAVE RADIOMETER FOR REMOTE SENSING OF ATMOSPHERIC MOISTURE.

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ABSTRACT

The MGO St-Peterburg Russia has designed ground-based microwave radiometric tools for investigations of atmospheric variables such as integrated cloud liquid water and integrated water vapor. Microwave radiometer for moisture sounding in real time operate in two frequency bands near line of vapor center 22.2 GHz and in transmission “window” of atmosphere near 35 GHz. A new low-cost, mass radiometer has highly stable total-power receiver, based on MMIC technology. Technical and tactical parameters of the original Dicke radiometer and new radiometer are compared. Calibrated brightness temperatures are used for estimations of water vapor and cloud liquid water content. Accuracy of determination of atmospheric parameters is about 10% (for water vapor), about 30% (for cloud liquid). The results of using such radiometers for atmospheric remote sensing in meteorological applications such as climate, weather forecasting, weather modification experiments are discussed.

Introduction

For the decision of the broad audience of problems of the meteorology connected with monitoring of an atmosphere and weather forecast, the operative information on characteristics of atmospheric moisture is necessary. Last years in MGO the special attention is given questions of perfection of a ground-based microwave tools for moisture sounding of an atmosphere and clouds. Theoretical aspects of the decision of a problem moisture sounding of an atmosphere are considered earlier in (Stepanenko V.D. et.al., 1987). Microwave radiometer intended for definition integrated water vapor and a integrated cloud liquid, usually registers intensity of own descending radiothermal radiation of an atmosphere on frequencies near to a line of absorption water vaporr of 22,235 GHz and “ a window of a transparency ” atmospheres of 30-38 GHz. One of optimum combinations of the frequencies, in practice for separate definition of integrated water vapor and integrated cloud liquid, the combination 21.0 (or 23.8) GHz and 36 GHz is used. The error of an estimation integrated water vapor makes about 10 %, and integrated cloud liquid –near by 30 %.

Principles of construction of the microwave-radiometers and the analysis of various schemes of the microwave-radiometers it is in detail executed earlier (Esepkina N.A., et.al., 1973, Ulaby F.T., et.al., 1981). The decision of the modern problem connected with equipment of a meteorological network by new devices of moisture sounding demands development and creation of a low cost, independently working microwave-radiometer.

Microwave radiometers for moisture sounding

In MGO during of some years development of the microwave radiometers for a range of frequencies of 10-90 GHz and experimental researches of integrated water vapor and integrated cloud liquid were carried out.

Traditional microwave-radiometer by MGO is constructed under the scheme modified modulated radiometer Dicke in which on an input of the receiver the antenna and stable controllable noise sources of a different level is consistently connected. Often for construction of a radiometer scale of in terms of antenna temperature it is used the internal stable noise of the operated generator calibrated by external procedures, for example on radiation of two absolutely black bodies at temperature 293 K and 79 K (liquid nitrogen). Stability of parameters of radiometer also is provided with stability of power supplies and temperature of electronic blocks and the antenna. Key parameters of such microwave radiometer are resulted in Table1.

Table 1. Characteristics of dual- channel radiometers
for determination water vapor and cloud liquid water content.

Parameter	Channel1	Channal2
Centre frequency, (GHz)	36.2	21.0
Bandwidth , (GHz)	0.40	0.40
Sensitivity, (K/sec$^{0.5}$)	0.3	0.3
Beamwidth, level 3 dB, (deg.)	10	10
Sampling time, (min)	1	1
Absolute accuracy, (K)	1	1

Development of the microwave radiometer of atmospheric moisture of new generation is connected with realization of requirements: i) low cost of manufacturing and operation and adaptability to manufacture; ii) high stability of parameters, reliability, portability, electromagnetic compatibility; iii) metrological maintenance of measurements of the microwave brightness temperature with a margin error is not worse 0.5-1 K.

Various variants of constructive decisions of microwave radiometric modules, focused on use of modern commercially-accessible element base are considered and realized. The developed microwave radiometric modules make a basis of the microwave-radiometric systems of atmospheric moisture sounding of new generation.

New microwave radiometric module RM-A is a sypergeterodine , working in a range of frequencies 22-31 GHz is intended for a spectral measurements near to a center of water vapor line of 22.235 GHz with the purpose of the operative control of integrated water vapor and integrated cloud liquid. Feature of radiometer is use of the common for all frequency channels

entrance low noise amplifier (factor of noise less than 3 dB) and mixer, executed with use of MMIC technology. Typical 1sec.- sensitivity makes nearby 0.2 K when bandwidth of IF amplifies is of 200 MHz (SSB). The RM-A has small dimensions (voluum is less 200 cm^3) and weight. The power consumed nearby 10 VA.

One of the purposes of modern researches was development technological microwave radiometric modules on the basis of MMIC HEMT GaAs low noise amplifiers (noise factor nearby 2dB). The microwave radiometric modules RM-B realizes the scheme of direct strengthening and detecting of full power, works in 8 mm a range of wavelengths, is intended for the operative control of integrated cloud liquid water contents. The volume of the radiometric module makes nearby 100 cm^3. Key parameters following: equivalent noise temperature of reception system makes nearby 200K, gain nearby 65 dB in a bandwidth of 6 GHz, small weight (about 0.2 kg). The module is equipped by system of temperature regulation and the electronic block of management of a feed, consumption makes nearby 5 VA.

Results

Experimental investigation of integrated water vapor and integrated cloud liquid water content have been conducted by the MGO during several years (Karavaev D.M., et.al., 1992, Karavayev D.M., et.al., 1998). Such studies were conducted in different geographical regions such as the Leningrad region, Europe (during BALTEX), during a see expedition in the Northern Atlantic. Numerous experimental researches of temporary variability of integrated water vapor and cloud liquid water in various regions both above ocean, and above a land which have found out high accuracy of integrated water vapor definition by microwave radiometry method are executed. For example, typically r.m.s. (radiometer-radiosounde) is 1.0-1.8 kg/m^2 in Leningrad region.

Fig.1 illustrates measurements of integrated water vapor and cloud liquid water contents in zenith direction by means of a ground-based dual-channel (22.2 GHz and 36.5 GHz) radiometer at Voeikovo (60°N, 30°E) in May 2007. The interpretation of these results was made using radiosounde data and weather station observations of temperature, humidity and pressure of surface air, and weather radar information. During period from 1 May to 21 May integrated water vapor changed over a wide range from 3.2 kg/m^2 up to 35 kg/m^2 and integrated cloud liquid is less than 1.2 kg/m^2 . The maximal values of integrated water vapor (near 30 kg/m^2) were marked on May, 14th during passage of the atmospheric front.

Fig.2 show temporal variabilities of integrated cloud liquid water measured on 27 August, 2008 by single channel microwave radiometer (wavelength 8.5mm) located in Voeikovo. This radiometer has high sensitivities nearby 0.02K/s½. During period of observations (duration is 8100sec.) integrated cloud liquid of stratiform clouds are changed from 0.02 kg/m^2 up to 0.11 kg/m^2.

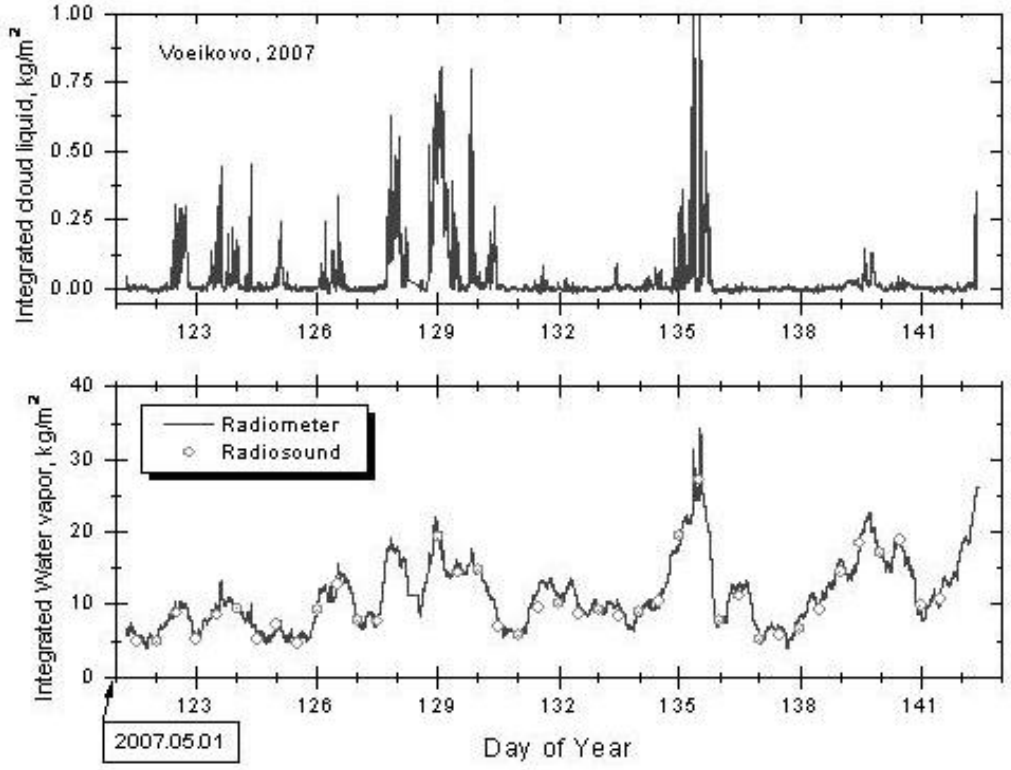

Fig.1 Time-series of integrated cloud liquid - (а) , and integrated water vapor - (б) obtained by means of dual-channel microwave radiometer located in Voeikovo

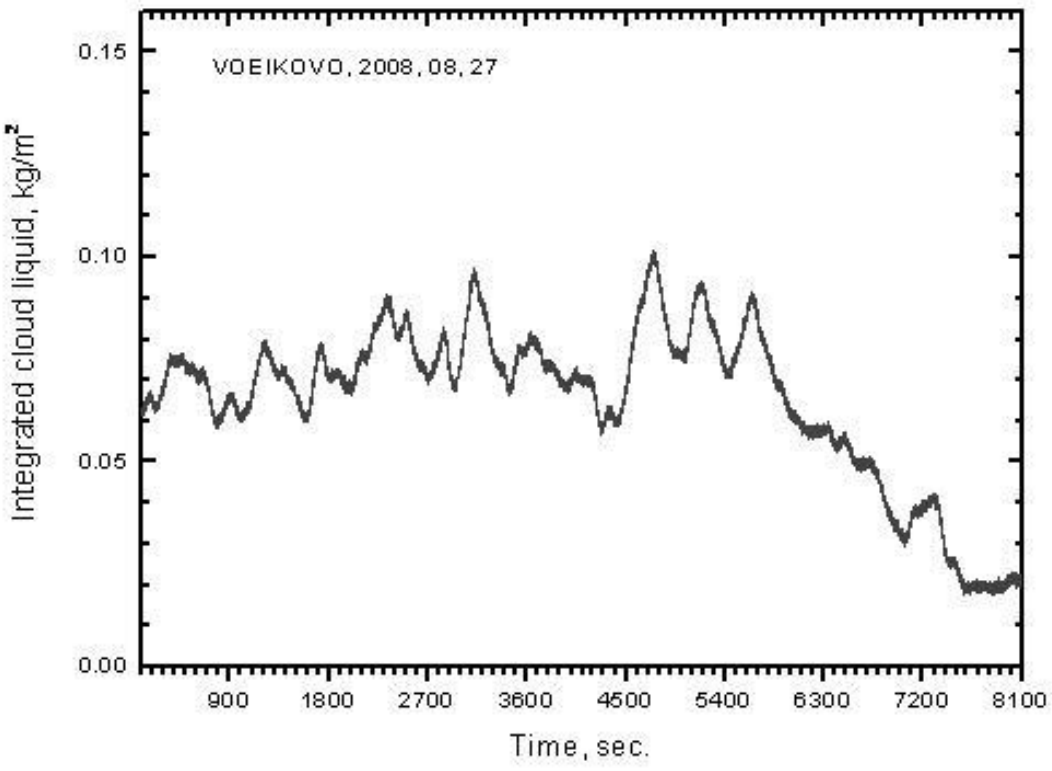

Fig.2. Time-series of integrated cloud liquid on 27 August, 2008 in Voeikovo.

Recent investigations (Shchukin G.G., et.al., 2008) demonstrate a possibility of application of the microwave radiometric information for evolution of the supershort-term forecast. Prospects of microwave radiometry method are determined by requirement of perfection of technologies of the short-term and supershort-term forecast, development of methods of mastering operative meteorological remote sensing including a ground-based microwave-radiometric network, radar and satellite informations of an atmosphere in regional mesoschemes of the numerical forecast.

Conclusion

Some versions of the microwave radiometric system for determination of integrated water vapor and integrated cloud liquid in continuis and “all weather” mode are designed . Tehnical and tactical characteristics these systems are investigated and compared. A new architecture of a low cost, portable, high sensitivities and high stability network microwave radiometric systems based on commercially eccessible components are studied.

Some results of long-term observations of integrated water vapor and integrated cloud liquid are discussed. The simultaneous measurements of integrated water vapor obtained by upper-air soundings suggest the high accuracy of radiometric measurement of atmospheric water vapor about 1kg/m^2 . The continuos observations have shown that the significant changes of integrated water vapor and integrated cloud liquid are related to synoptic situation changes in atmosphere.

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