Microwave balloon measurements of the stratospheric temperature

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The results of balloon flight with nadir microwave thermal sounding launched on 25 July 1990 from Rylsk base are presented. Radiometer without image rejection operating at the slopes of 9^+ and 11^- oxygen resonance lines and having 6 channels with bands of 3-150 MHz and sensitivities of 0.6-0.09 K has been used.

1 Introduction

Temperature is one of the important atmospheric characteristics. The data of thermal sounding from satellite are used to obtain the temperature profiles in global scales. However, most of the existing satellite units make measurements only up to 20-25 km (Ref. 1). It is proposed to determine stratospheric temperature by means of high-sensitivity multichannel radiometer operating at 5 mm. A new method of signal processing has been used in the design of the radiometer.

2 Method of the line convolution

Remote determination of the atmospheric temperature is based on measurements of radiation from molecular oxygen having a set of strong absorption lines in the frequency range 55-65 GHz (Ref. 2). The brightness temperature proportional to the radiation intensity is related to the atmospheric temperature by Fredholm integral equation of the first kind. The kernel of this equation is the weighting function which determines the contribution of each atmospheric layer to the brightness temperature. For nadir thermal sounding the weighting function reaches a maximum at a particular height which depends on the channel frequency. In order to increase the sounding height up to 40 km one must operate near resonance in the narrow bandwidth of about 3 MHz (Ref. 3). However, radiometer channel with such a narrow band has insufficient sensitivity. A new method of signal processing has been proposed to improve the sensitivity. It is based on synchronous measurements of the radiation at two frequencies which are symmetrically located relative to each of the resonant frequencies 57.612 and 61.151 GHz of two oxygen lines with approximately identical shapes and intensities. Such technique is realized by the use of double frequency

conversion so that the first and the second local oscillator frequencies are equal to a half sum and a half difference of the resonant frequencies, respectively.

3 Instruments

The radiometer has a horn antenna with a beamwidth of 8° and very low sidelobe level so that antenna temperature is approximately equal to the brightness temperature. Solid-state Dicke radiometer has an original first mixer with loss of 3 dB and noise temperature of 300 K. Signals from antenna and reference load are received by first and second input wave guides with Shottky diodes. The first local oscillator is an original Gunn-effect diode with low power consumption. The frequency stability determined by invar resonator is 0.5 MHz. Field-effect transistor amplifier is used as the first intermediate frequency amplifier with a power gain of 30 dB, noise temperature of 100 K and bandwidth of 700 MHz. The total equivalent noise temperature of the receiver does not exceed 600 K. After amplification the signal is transformed by a second mixer. The second local oscillator is a bipolar transistor with frequency instability of 0.5 MHz. The equipment is placed in a container with internal temperature of 35°C. The total weight of the container with equipment is about 40 kg. Radiometer parameters are given in Table 1.

4 Balloon experiment

In order to test the equipment under low stratospheric temperature conditions and to verify the correctness of processing methods, a balloon flight with the microwave radiometer was made from Rylsk (52°N, 35°E). The flight with nadir sounding took place on 25 July 1990 in heavy cloud conditions during 0800-1100 hrs LT. The schedule of the flight included the 1.5 hr ascent up to 30 km, the 0.5 hr drift

Table 1—Radiometer parameters

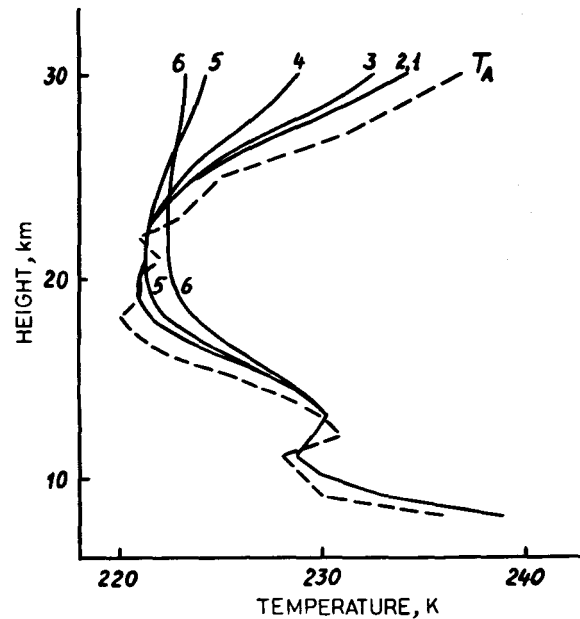| Channel No.	Channel frequency MHz	Band- width MHz	Sounding height km	Vertical resolution km	Sensi- tivity K
1	5	3	41	12	0.6
2	9	6	36	11	0.5
3	21	15	31	10	0.3
4	45	30	26	9.6	0.2
5	110	72	21	9.2	0.14
6	220	150	18	8.6	0.09

Fig. 1—Vertical profiles of the atmospheric temperature (dashed line) and brightness temperatures for all channels (solid lines) (figures denote channel numbers.)

at this altitude and the descent of the container with a parachute. Onboard thermistor was used to make contact measurements of the atmospheric temperature. All the data were transmitted to the ground by 32-channel radio telemetry system and recorded on magnetic tape for computer processing.

5 Results

Figure 1 shows the dependencies of brightness temperatures measured during the flight on the balloon altitude. In the troposphere, the brightness temperature of each channel reproduces the altitude profile of the atmospheric temperature with a deviation of 3-4 K. This means that, in the troposphere each channel operates as a thermometer registering the temperature of the ambient air. It is caused by the strong absorption of radiation in the troposphere (2-3 Np/km). During the ascent of the balloon the graphs of the brightness temperatures of the channels subsequently deviate from the air temperature profile because of the decrease in absorption. It can be seen that curves of 6th, 5th and 4th channels tend to approach a constant level corresponding to air temperature of the atmospheric layer where the maximum of the weighting function for the channel is located. The curves of the other channels reproduce the temperature profile, because their weighting function peaks are located higher than 30 km. The brightness temperature values measured during the nadir sounding were used to restore stratospheric temperature profiles with the application of regression technique. The regression dependencies were derived with the use of Rosenkranz's model[4] and 7 real atmospheric temperature profiles obtained during the radiosonde measurements by con-

tact sensors. The temperature was restored with an accuracy of within 3 K at the heights of 18, 22 and 27 km, corresponding to maxima of the weighting functions of channels 6, 5 and 4. Unfortunately, the limited height of the ascent (30 km) did not allow restoration of the temperature profile of the stratosphere up to 40 km on the basis of data of channels 3,2 and 1, having maxima of the weighting functions at the heights of 31, 36 and 41 km, respectively.

6 Conclusions

The experiment has revealed reliable operation of the device and allowed a test of data processing procedure. It has been confirmed experimentally that it is possible to determine the stratospheric temperature by means of a microwave radiometer.

References

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