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GROUND-BASED MICROWAVE INSTRUMENT TO RESEARCH OF STRATOSPHERIC OZONE (SOME RESULTS OF OBSERVATIONS)

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Abstract. Two decades have passed from the date of the start of microwave studies of polar ozone in Russia (Kola Peninsula, Apatity (67°N, 35°E)). At present we have obtained important results about the structure of vertical distribution of ozone in the Arctic middle and upper stratosphere [1-3].
Millimeter-wave spectrometers are considered now as the most actual instruments for monitoring stratospheric ozone and other minor gas constituents [4-8].
All results were obtained using microwave technique which has big dimensions, complicated antenna system and can not be easily transported to another site of observation. Some scientific tasks require the development of portable microwave instrument for ozone measurements and new approach for design.
Besides, in the paper, we present some recent results which have been obtained with the help of the new microwave device [9].

New ground-based equipment solutions

The development of new components has allowed a simple heterodyne for MM-receivers adjusted on the fixed frequency (up to 230 GHz). The block diagram in Fig. 1 shows elements of microwave instrument and its interconnection.

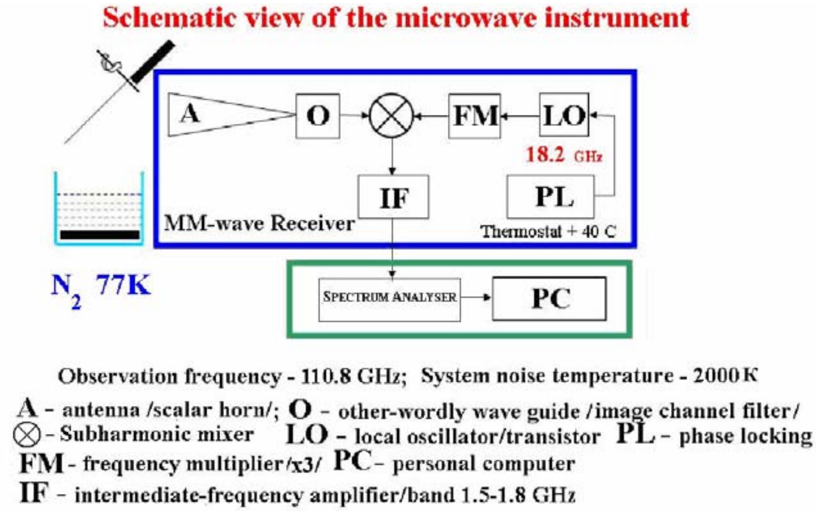

Fig. 1

The instrument consists of an uncooled MM-wave receiver and multichannel spectrometer. The MM-wave receiver is set up on fixed frequency. Observation frequency: 110.8 GHz. Relative frequency instability 10^{-7}. Image channel filter – other-worldly wave guide. System noise temperature (SSB) – 2000 K. Weight of the MM-wave receiver – less than 10 kg. Dimensions 500×225×125 mm. Figure 2 presents a photo of input circuits MM-wave receiver without the antenna (scalar horn). On the right in the photo the image of a channel filter (other worldly wave guide) is presented. It has direct losses less than 1 dB, and suppression of the mirror channel more than 20 dB.
The multichannel spectrometer represents a bank of filters with spectral bandwidth 240 MHz and the variable frequency resolution: 1.0 – 10 MHz. Main power less 150 W. Parameters of the instrument allow to receiving the information (for 15 minutes – time resolution) on vertical distribution of ozone at heights from 20 up to 60 km. The measurements of spectra of atmospheric emission were carried out both by the method of variation of zenith distance and by the method of its calibration on hot and cold reference loads.

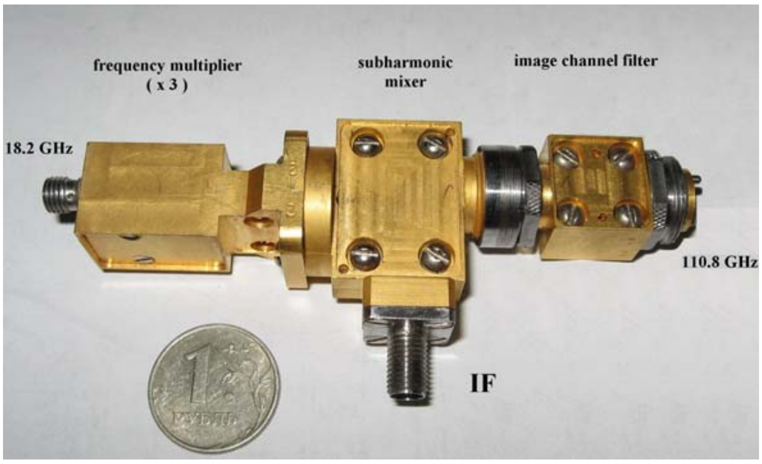

Fig. 2 Input circuits heterodyne MM-wave receiver at 110.8 GHz

Low ozone in the Arctic summer stratosphere near the North Pole. Microwave measurements at Ice-breaker «Captain Dranitsyn» during navigation Murmansk-Severnaya Zemlya-Murmansk.

On data TOMS (Earth Probe) in the summer 2005 near the North Pole there was steadily low total ozone (less than 300 DU). It is of interest to estimate vertical distribution of ozone - i.e. to determine, at what heights, there was a decreasing of ozone. The reason of reduction of stratospheric ozone could be strong solar storms of last time (October, 28 2003 and last decade January 2005) [10, 11].
For the first time the portable microwave device was used for measurements of stratospheric ozone in the Arctic polar latitudes from a board of the ship. Ice-breaker «Captain Dranitsyn» carried out tourist cruise over a route Murmansk – Severnaya Zemlya - Murmansk (general extent ~ 7500 km) from August, 9 till August, 24, 2005. The Mys Arktichesky (81°N, 95°E) Archipelago Severnaya Zemlya was a final point of the route.
The purpose of our voyage was a research of the vertical structure of ozone layer at heights of a middle and upper stratosphere. Extraordinary low total content of ozone with the large space of a covering was observed (see Figure 3, 4). Top and middle panel in Fig. 3 daily average data about total ozone – TOMS, Earth Probe and hourly average microwave data about the ozone content at heights 22 km accordingly are cited. On the bottom panel in Fig. 3 displays the variations of tropospheric attenuation during measurements of ozone spectra. In Fig. 4 shows spectra of ozone lines which were measured during movement of an ice-breaker from Mys Arktichesky to Island Golomyanny. These spectra demonstrate significant variations of the ozone content (above 22 km) from 56.3 DU up to 108.9 DU. Satellite measurements TOMS confirm these changes (see Fig. 3).
In summer observations of ozone in polar latitudes (70°N – 81°N) from a board of the ice-breaker was received unexpected result. The low ozone content was measured in layer 22-60 km (at three times less than norm). The vertical distribution of O_3 was broken at heights 22-35 km aside essential reduction. The ozone density above 35 km did not differ from summer model of vertical distribution.

Variations of ozone during a total solar eclipse March 29, 2006 (microwave radiometry data)

Microwave observations of stratospheric ozone were carried out during total solar eclipse March, 29, 2006 in Kislovodsk (43.7°N, 42.7°E) at High-mountainous scientific station of the Obukhov Institute of Atmospheric Physics, Russian Academy of Sciences (height above sea level ~ 2070 meters). Circumstances of an eclipse: Kislovodsk the beginning of an eclipse at 14:03, the greatest phase at 15:17 and the end at 16:28 (time Moscow). The width of a strip of an eclipse made about 200 km. Duration of a full phase of 2 minutes of 32 seconds. The altitude of the Sun above the horizon made near 40°.
Fig. 5 shows dependences of intensity the 110.8 GHz line emission of ozone in the stratosphere and lower mesosphere (the top panel) and tropospheric attenuation from time in day of a total solar eclipse. Each point on the plots corresponds to time resolution of about 12 minutes. Fig. 6 shows the changes of an ozone density (integration time for each point one hour) at heights 25, 40 and 60 km in day of an eclipse March, 29, 2006. Horizontal lines show average sizes of night ozone density from 20:57 28.03.06 till 07:07 29.03.06 and from 18:59 29.03.06 till 03:05 30.03.06, and also day ozone from 06:55 till and 15:56 till 19:11 29.03.06. Besides the average size of O_3 density is resulted during a solar eclipse (an integration time about two hours). The density of night and day time ozone for two intervals of time has made $(8.10\pm0.39)\cdot10^9$ cm^{-3} and $(7.00\pm0.16)\cdot10^9$ cm^{-3}, $(5.11\pm0.13)\cdot10^9$ cm^{-3} and $(5.00\pm0.17)\cdot10^9$ cm^{-3} accordingly. Average O_3 density during an eclipse - $(7.20\pm0.26)\cdot10^9$ cm^{-3}. Thus, the increase of ozone density at altitude of 60 km during an eclipse made about 40 %.

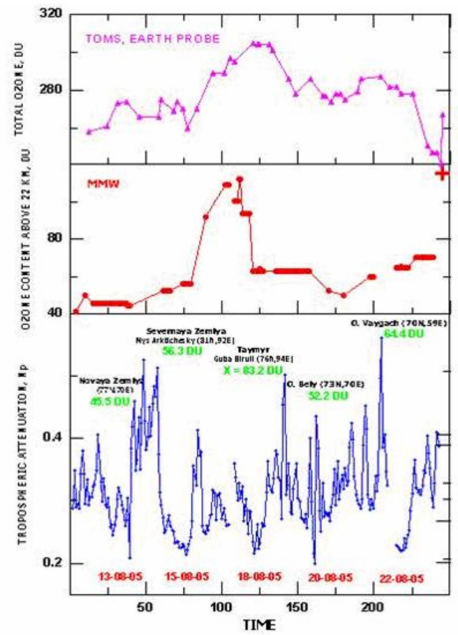

Fig. 3 Variations of ozone and tropospheric attenuation during navigation of the ice- breaker on a route Murmansk-Severnaya Zemlya-Murmansk.

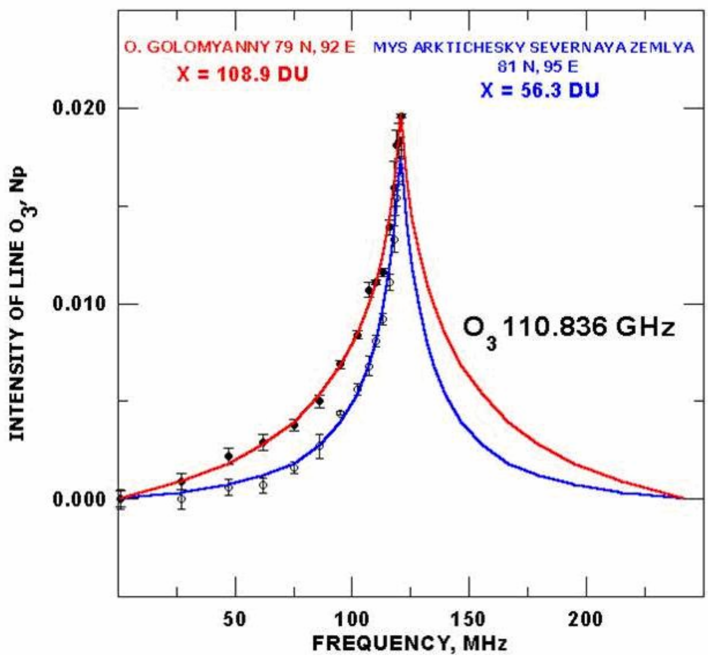

Fig. 4 Ozone spectra observed August 15 (empty circles) and August 16 (filled circles), 2005, superimposed with synthetic spectra calculated from a retrieved ozone altitude distribution (the top and bottom continuous curves).

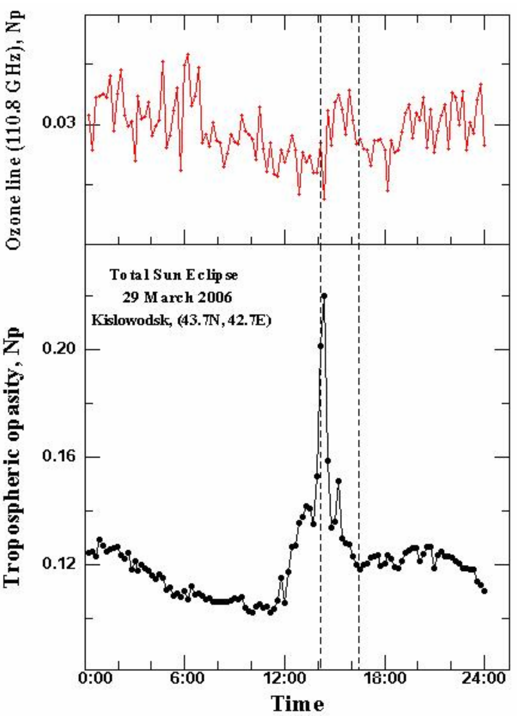

Fig. 5. Variations of intensity atmospheric line of ozone (resonant frequency 110.836 ГГц) and tropospheric attenuation in day of a total solar eclipse March, 29, 2006 (vertical dashed lines designate the beginning and the end of an eclipse).

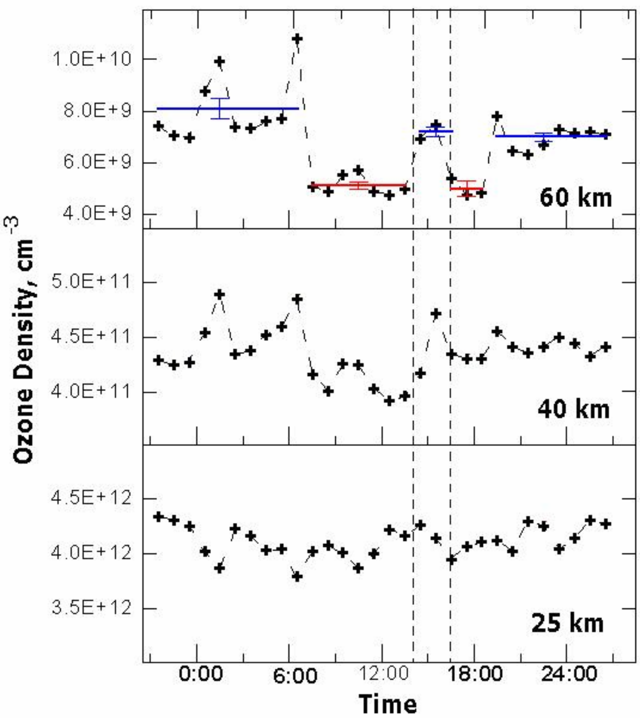

Fig. 6. Changes of ozone density at heights 25, 40 and 60 km during total solar eclipse.

During an eclipse the increase of mesospheric ozone is registered.

The ozone density at height 60 km increased by 40%.

Amplitude of mesospheric ozone changes (60 km) during a total solar eclipse did not differ from its diurnal variations (sunrise and sunset).

Significant variations of water vapor in the low troposphere, apparently, connected with the movement of lunar shadow are found.

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