ON-ORBIT CALIBRATION OF THE “METEOR-M” MICROWAVE IMAGER/SOUNDER

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1. INTRODUCTION

The Meteor-M N 1 spacecraft with microwave radiometer MTVZA-GY has been launched on September 17, 2009 on sun-synchronous orbit at an altitude of 830 km. The instrument MTVZA-GY is a microwave imager/sounder [1]. It will be used as the meteorological imaging system for remote sensing of ocean and land surface parameters as well as for measuring global atmospheric temperature and water vapor profiles together with some integrated parameters of atmosphere and clouds. MTVZA-GY instrument is shown in Fig. 1 (left) and its characteristics are given in Table 1.

Table 1. MTVZA-GY performance characteristics

System	MTVZA-GY
Frequency (GHz)	10.6, 18.7, 23.8, 31.5, 36.5, 42.0, 48.0, 52.3-57.0, 91.65, 183.31
Spatial resolution (km)	16-198
Swath width (km)	1500
Conical scanning period (sec)	2.5
Instability Scanning Period	10^{-4}
Mass (kg)	90
Power Consumed (W)	80

The microwave imager/sounder MTVZA-GY operates at frequencies of 10.6, 18.7; 23.8; 31.5; 36.5; 42.0; 48.0 and 91.65 GHz with vertical (V) and horizontal (H) polarization, 52.80, 53.30, 53.8, 54.64 and 55.63 GHz with V polarization, 56.87- 57.71 GHz (10 channels at low-frequency slope of strong molecular oxygen absorption band) and 186.31 - 190.31 GHz (6 channels in neighborhood of a strong water vapor absorption line centered at 183.3 GHz) with H-polarization. The instrument will provide measurements of atmosphere temperature profile to approximately 42 km and water vapor profile to 6 km. The measurements at frequencies of 10.6, 18.7; 23.8; 31.5, 36.5, 42.0, 48.0 allow to retrieve the sea surface and integrated atmospheric parameters [2, 3].

2. INSTRUMENT

The microwave radiometer MTVZA-GY is based on the technology of combining in space and time multi-frequency and polarization measurements [4]. The antenna system of MTVZA-GY consists of an offset parabolic reflector of dimension 65 cm, illuminated by four feed-horns antenna. To remain the invariant of viewing angle and polarization in scanning sector the reflector and feed-horns antenna are mounted on a drum, containing the radiometers, digital data subsystem, power and signal transfer assembly, which rotates continuously about an axis parallel to the local spacecraft vertical. The power, commands, all data, timing and telemetry signals pass through slip ring connectors to the rotating assembly. The total-power radiometer configuration is employed. The channels of 10-48 GHz are the direct amplification radiometers. The channels of 52-57 GHz, 91 GHz and 183 GHz are built as superheterodyne receivers using balanced mixers. MTVZA-GY microwave performance and channel characteristics are shown in Table 2. MTVZA-GY scanning geometry is shown in Fig. 1 (right). The MTVZA-GY scanning platform period is 2.5 s during which the sub-satellite point travels 16 km. The scan direction is from the left to the right when looking in the aft direction of the spacecraft, with the active scene measurements lying from –90° to +15° about the aft direction, resulting in a swath width of 1500 km. The viewing angle is 53.3° and the incidence angle with respect to the Earth surface - 65°. The sampling rate is 16x16 km for all microwave channels. To provide required sensitivity the size of imagery pixel differs depending on channels frequency ν. The sensitivity of radiometer channel has been confirmed on-orbit condition (Table 2).

3. CALIBRATION

The main attention is given to discussion of $T_B(\nu)$ calibration. For calibration the hot reference absorber and small mirror are used. They are mounted on the non-rotating part of instrument and are positioned such that they pass between the feed-horns and parabolic reflector, occulting the feed-horns once each scan. The mirror reflects the cold cosmic background radiation of 2.7 K into the feed-horns.

Besides, external calibration was suggested and tested. The regions in the open ocean surrounding Antarctica were selected as a cold reference. The $T_B(\nu)$ variations in these regions were computed by numerical integration of microwave radiative transfer equation using radiosonde-derived vertical profiles of atmospheric pressure, temperature and humidity obtained by coastal stations and research vessels during cloudless sky at weak winds (3± 1 m/s), low values of total water vapor content (3 ± 1 kg/m^2) and sea surface temperature (SST) values from -1.8 to 10°C. The ranges of T_Bs were determined for all semitransparent channels. The experimental MTVZA-GY data at H-polarization were screened to reveal the regions the size of approximately 20x20 pixels and larger near

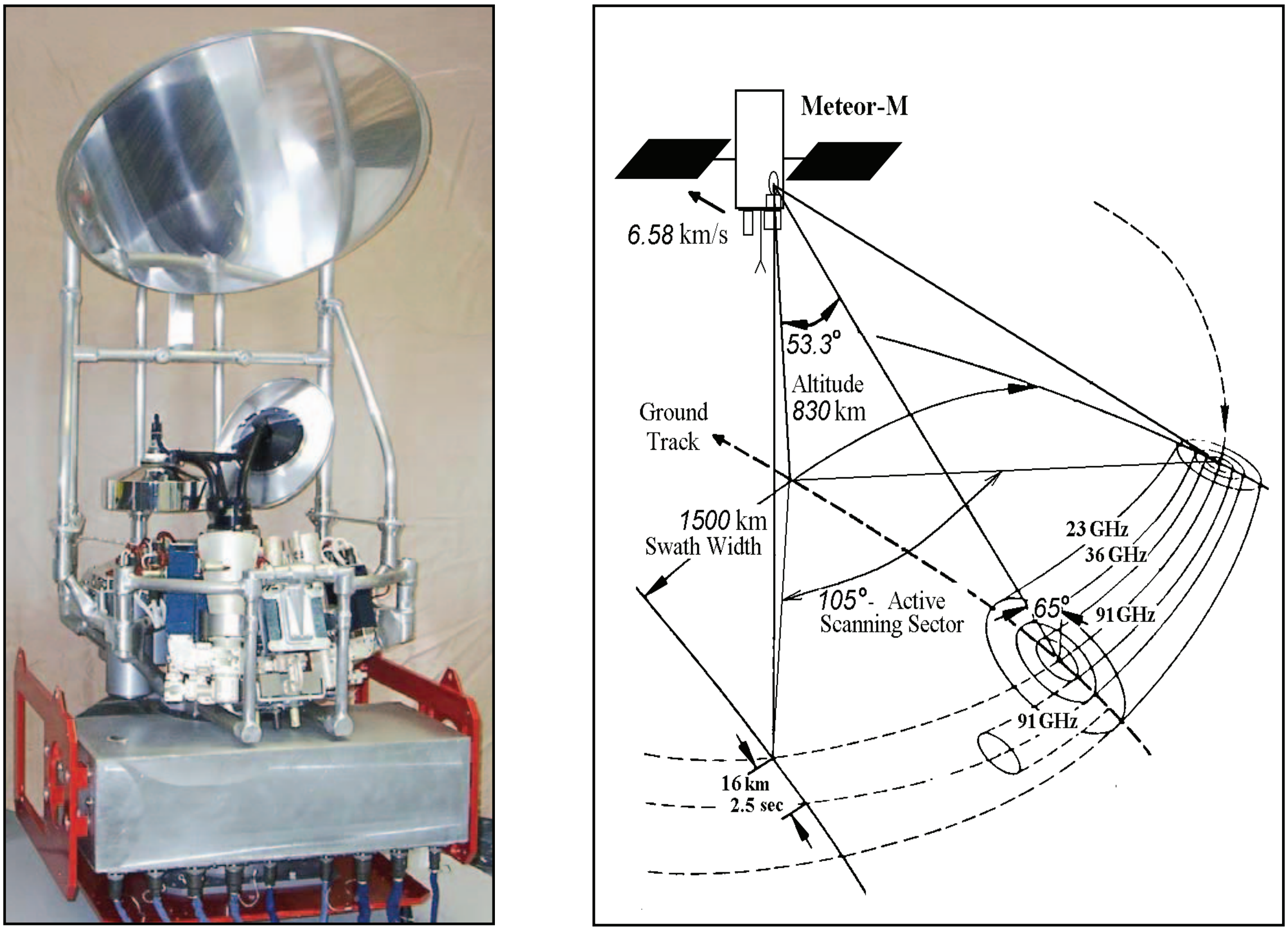

Fig. 1. Microwave imager/sounder MTVZA-GY (left) and (b) MTVZA-GY scanning geometry (right)

Antarctica where signals were characterized by minimum values. The brightness temperatures of these areas were assumed equal to the computed $T_{\mathrm{Bmin1}}(\nu) \pm \Delta T_{\mathrm{B}}(\nu)$. The similar procedure was performed for the tropical forest areas, which served as a natural hot reference. Brightness temperatures over the tropical forest areas were computed for the given values of the underlying surface temperature and emissivity (0.96-0.98) and radiosonde profiles for cloudless conditions.

Examples of T_{B}s measurements over the ocean are considered. Experimental data are compared with the simulated brightness temperatures to show the spectral differences in influence of the oceanic (sea surface temperature and sea surface wind speed) and atmospheric (total water vapor content and total cloud liquid water content) parameters on the brightness temperatures. Meteor-M MTVZA-GY brightness temperatures were also compared with Aqua AMSR-E measurements and Terra and Aqua MODIS images acquired over various marine weather systems.

TABLE 2. MTVZA-GY microwave frequency channel characteristics

Channel Number	Frequency (GHz)	Number of Bands	Band Width (MHz)	Effective FOV (kmxkm)	Imagery pixel (kmxkm)	Instrument Sensitivity (K/pixel)	Approximate peak sensitivity altitude (km)
1	10.6	1	100	89x198	32x32	0.5	-
2	18.7	1	200	52x116	32x32	0.4	-
3	23.8	1	400	42x94	32x32	0.3	-
4	31.5	1	1000	35x76	32x32	0.3	-
5	36.5	1	1000	30x67	32x32	0.3	-
6	42	1	1000	26x60	32x32	0.4	-
7	48	1	1000	24x43	32x32	0.4	-
8	52.80	1	400	21x48	48x48	0.4	2
9	53.30	1	400	21x48	48x48	0.4	4
10	53.80	1	400	21x48	48x48	0.4	6
11	54.64	1	400	21x48	48x48	0.4	10
12	55.63	1	400	21x48	48x48	0.4	14
13	57.290344±0.3222±0.1	4	50	21x48	48x48	0.4	20
14	57.290344±0.3222±0.05	4	20	21x48	48x48	0.7	25
15	57.290344±0.3222±0.025	4	10	21x48	48x48	0.9	29
16	57.290344±0.3222±0.01	4	5	21x48	48x48	1.3	35
17	57.290344±0.3222±0.005	4	3	21x48	48x48	1.7	42
18	91.65	2	2500	14x30	16x16	0.6	surface
19	183.31 ± 7.0	2	1500	9x21	32x32	0.5	1.5
20	183.31 ± 3.0	2	1000	9x21	32x32	0.6	2.9
21	183.31 ± 1.0	2	500	9x21	32x32	0.8	5.3

1. REFERENCES

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