

Black Body Targets for Calibration of Microwave / Millimeter Wave Radiometers

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Abstract— Earlier Black Body Targets (BBT's) were designed and used for the ground calibration of Multi-frequency Scanning Microwave Radiometer (MSMR) and Ocean Color Monitor (OCM) payloads that were flown on-board OSEANSAT-1 (IRS-P4) Satellite. The BBT's were designed to be used in a thermo-vacuum chamber and operative from 78K to 320K. The BBT's, as desired, had very high emissivity (> 99.95 %) over the full frequency range from 6.6 GHz to 21.0 GHz. Flight data confirmed that calibration coefficients provided by ground calibration using the BBT's were accurate. Recently we developed BBT's for millimeter wave sounders for radiometer calibration over 23 to 90 GHz frequency band. These BBT's had to be space qualified and would be used as hot sources on-board the satellite. In view of this the absorbing units were made of array of hollow aluminum pyramids coated by space grade thin absorbing paint to keep total weight of BBT's to its minimum. To begin with a scaled down model was developed involving material qualification, process qualification, environmental test and emissivity measurement (> 0.995). Design Verification Model (DVM) versions of the BBT's have also been made and approved. A Flight Model (FM) to be flown with the Satellite, which is going to be simple extension of DVM Versions, is yet to be procured.

I. INTRODUCTION

The Absolute accuracy of microwave remote sensing radiometers is an important consideration for many applications. One method of achieving absolute radiometer calibration is through the use of blackbody calibration targets to provide reference brightness temperatures for the radiometer to view. These targets are widely used with space born, airborne and ground-based microwave instruments.^[1]

II. BLACK BODY TARGET (BBT) FOR GROUND CALIBRATION

Earlier Two BBTs were designed and developed by one of the authors (Dr.K.Lal) when associated with K.V. Microwave Materials (KVMM) for ground calibration of the MSMR. Multi-frequency Scanning Microwave Radiometer (MSMR) and Ocean Colour Monitor (OCM) were the two payloads that were flown on board Ocean set-I (IRS-P4) on May 26 1999 from SHAR, ISRO. These BBTs were designed with a goal of achieving very high emissivity (≥ 0.999) which corresponds to very high reflection loss/absorbance in the operating frequencies of 6.6, 10.65, 18, and 21GHz having low thermal gradient from top to bottom. Prior to full scale model, a scaled down model was made by KVMM with required measurement test bed. To achieve this, absorbing material (coating) was tested in

thermovac condition for TML, CVC, Thermal Diffusivity, Specific Heat, Thermal Conductivity, Sample Density and Return Loss over the full operating range.

The scaled down model of the BBT comprising 3x3 absorbing material coated Copper pyramids was tested by return loss maximum and minima method. Subsequently, as further confirmation the emissivity of BBT was tested at Defense Lab, Jodhpur. The emissivity of the BBT Sample was better than the designated value of 0.999 at all frequencies. The thermal gradient test on the Sample was also carried out. Based on the above, 3 full scale BBTs (One Earth Target, One Sky Target-1 for 6.6 GHz and 10.65 GHz and One Sky Target-2 for 18 and 21 GHz) were successfully developed whose performance met the specification laid down by MSMR Project. An article entitled "Ground Calibration of Multi frequency scanning Microwave Radiometer" by Tapan Mishra *et.al.* was also published on the subject giving details of ground calibration operation such as shown in fig.1.^{[2][3]}

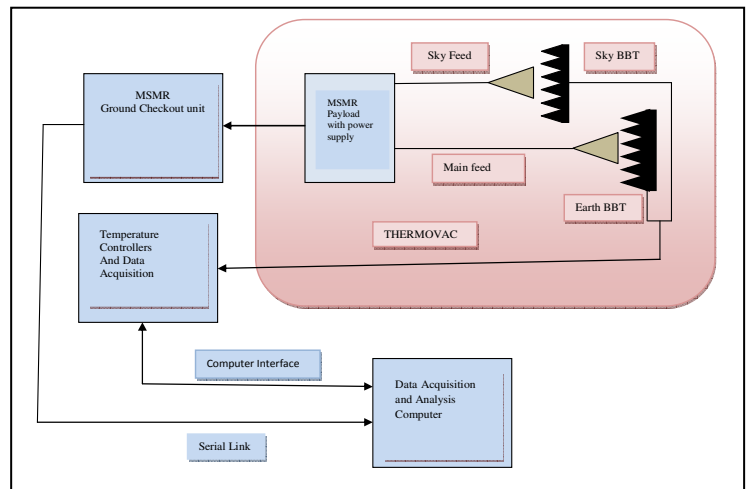


Fig.1. MSMR test setup in thermovac chamber.^[3]

III. BBT AS HOT SOURCES FOR ON-BOARD SATELLITE

As a part of advanced R&D Projects, Millimeter wave sounder projects were planned by ISRO. This project will consist of the development of two units of Temperature Sounding Unit (TSU) and Humidity Sounding unit (HSU). The TSU will cater to the 23/31 GHz and the 50-60 GHz band of frequencies. The HSU will cater to the 89 GHz and the 183.31 GHz channels. Sounder is basically a radiometer which maps the vertical profiles of the atmosphere. Thus like all radiometers the absolute calibration accuracy requirement of the

sounder is very high and is of utmost importance for its final remote sensing utility. In order to achieve high calibration accuracy it is needed to have highly accurate blackbody targets as hot sources on-board the satellite for each of the concerned reflectors/feeds (4 in our case).

The blackbody targets have to be designed with a goal of achieving very high emissivity (~0.995). Blackbody targets have to be designed and fabricated and the required measurement test-bed for measuring the achieved reflectivity/emissivity has to be acquired for the project. Prior to Flight Model development, a scaled down model (SDM), as detailed below was planned to be designed and developed and subjected to space level qualification testing to ascertain the soundness of the design.

(A) Scale Down Model (SDM) for On-Board Satellite

Specification of BBT Scaled Down Model (fig.2)

Black Body Emissivity	≥0.995
No. of Pyramid	121
Size of Pyramid	50mm Height X 14mm base(dimensions include coating)
Coating Thickness	1.5mm approx
Coating Material	Absorbing Powders in Binder such as epoxy, RTV
Size	154mm X 154mm(Single piece)
Tolerance on Size	±0.05mm
Pyramid Material	AL6061
PRT accuracy	0.1K
No of PRT	Approx. 15 Nos.
Position of PRT	To be placed from back Side of pyramids but very close to the front surface.
Weight of Pyramid	Approx 10 to 12 kg (with coating)

(A) Mobile Target (Fig.3)

For emissivity/Reflection Loss of SDM of BBT

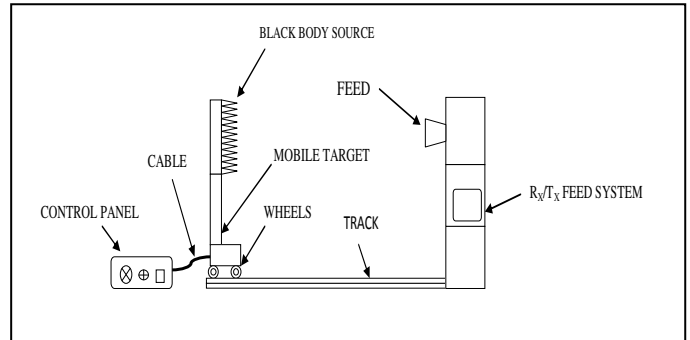


Fig.3.Schematic diagram for black body source testing

(B) ENVIRONMENT TESTING SPECIFICATION FOR COATING

(a) THERMAL SHOCK TEST

Cold Temperature: -115±3 deg.c. For 5 minutes.
 Hot Temperature: +115±3 deg.c. For 5 minutes.
 Heating/Cooling rate: -10 deg.c.±2deg.c.min.
 Number of cycles: 100

(b) HUMIDITY TEST

Temperature: 48±2 deg.c. For 5 Minutes
 Humidity: 95%RH ±5RH
 Duration: 10 Days

(c) THERMO VACUUM TEST

Cold Temperature: -115±2 deg.c. For 24 Hours.
 Hot Temperature: +115±2 deg.c. For 24 Hours.
 Vacuum: 1 X 10⁻⁶ Torr
 No. of Cycles: 5

(d) BEND ADHESION TEST

The samples as applicable shall be inserted in the apparatus fitted with mandrel diameter of 8 mm, so that it may be subsequently bend with the coated side outwards. Close the apparatus evenly without jerking over a period for 1-2 seconds thus bending the panel over the mandrel through 180 deg.

(e) ADHESION TEST

Make evenly parallel (6X2 parallel cuts), cuts approximately 30 mm long and 2 mm apart by a sharp razor blade knife or other cutting device up to the base metal. Then place the pressure sensitive tap (600 gram/inch) over the lattice pattern of cuts. After the two minutes of application pull the tape rapidly at right angle to the surface and inspect the grid area of coating.

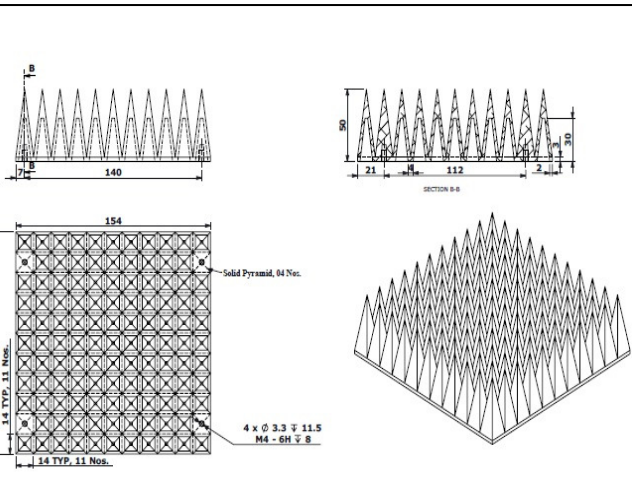


Fig.2. Scaled Down Model of Black Body Target (BBT)

V. FUTURE WORK

A Flight Model (FM) to be flown with the Satellite, which is going to be simple extension of DVM Versions, is yet to be procured.

VI. REFERENCES

[1] James Randa, David K. Walker, Amanda E. Cox and Robert L. Billinger "Errors resulting from the reflectivity of calibration targets" IEEE Trans on Geosciences and Remote Sensing" Vol. 43, No.1, pp50-59, 2005

[2] Dr. Kanhiya Lal "Contributions of K.V. Microwave Materials, Ideal K.V. Microwave Products & Sahajanand Laser Technology to RS Activities" Signatures, Newsletter of the ISRS-AC, Vol. 23, No.1 & 2, Jan-Jul 2011

[3] Tapan Mishra, A.M. Jha, Deepak Putrevu, Jogeswara Rao, D.B. Dave and S.S. Rana "Ground Calibration of Multi frequency scanning Microwave Radiometer" IEEE Trans on Geosciences and Remote Sensing" Vol. 40, No.2, pp504-508, 2002

(f) VISUAL INSPECTION OF COATED SAMPLES

Visual inspection shall be carried out at 10x magnification. Higher magnification can be used to resolve any ambiguity and for further confirmation. Visual inspection shall be carried out before and after each environmental test.

(g) EMISSIVITY MEASUREMENT

Emissivity measurement should be carried out by Emmissio meter and also by standing wave ratio based reflectivity measurement. ($\geq 0.996 = > \text{Reflection loss} - 23.98\text{dB}$)

IV. DESIGN VERIFICATION MODEL (DVM) VERSION OF BBT

After successful completion of scale down model a DVM of BBT's was planned as shown in fig.4. In these models, the curved metallic base were made by ISRO and absorbing coating was done by SLTL. The DVM versions have been successfully done.

Specification of BBT Design Verification Model (Fig.4)

Frequency Range	23-31 GHz
Black Body Emissivity	>0.95
No. of Pyramid	910
Size of Pyramid	50mm Height X 14mm base (dimensions include coating)
Coating Thickness	0.5 to 1 mm approx
Coating Material	Absorbing Powders in Binder such as epoxy, RTV
Size	364mm X 324.9mm (Single piece) as per fig.4
Tolerance on Size	$\pm 0.05\text{mm}$
Pyramid Material	AL6061

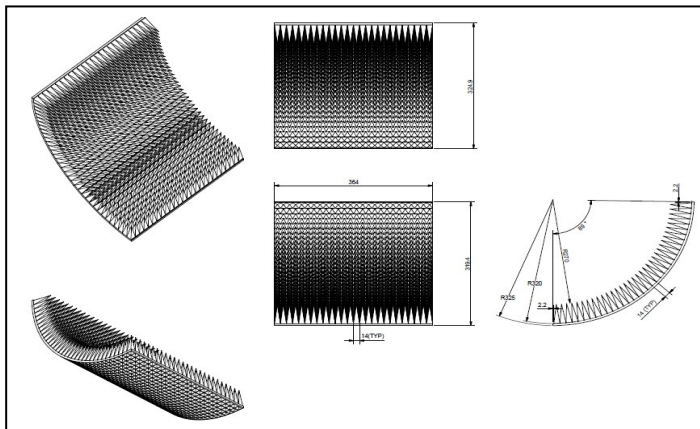


Fig.4. Flight Model (FM) Black Body Target (BBT)