Appendix F

Baseplate Pyramid Modelling of the Calibration Target for the MetOp-SG Microwave Sounder Instrument (MWS)

Katherine Ostojic
(RAL Space, United Kingdom)

Abstract

The Microwave Sounder instruments (MWS) are being built with Airbus Defence and Space (UK) as prime contractor. MWS, flying on the MetOp Second Generation A spacecraft, will make measurements from 23 to 229 GHz for operational meteorology. MWS will be calibrated pre-launch in a thermal vacuum using blackbody targets developed at STFC RAL Space, in Oxfordshire, UK. The variable temperature target, representing the Earth view of MWS, uses a liquid nitrogen / helium gas gap system to control the target temperature to between 80 K and 315 K. The baseplate of the 500 mm diameter target is required to be as isothermal as possible and, in order to approximate a blackbody, the aluminium target surface is machined to contain 2500 square pyramids, each 9 mm wide at base and 40 mm high. These are conformally covered by circa 1.5 mm of low thermal conductivity absorber. These pyramids have proven to be challenging to model using a finite difference method in ESATAN-TMS. A modelling method has been developed which uses the radiative aspects of ESATAN-TMS to determine the heat load on the surfaces of these pyramids. These outputs, in combination with a more detailed finite element ANSYS model of a single pyramid, better determine the temperature distribution through each pyramid for the calculation of physical and brightness temperatures. This talk will examine the lessons learned during the modelling process and the rationale behind the selection of the final analytical method.

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Baseplate Pyramid Modelling of the Calibration Target for the MetOp-SG Microwave Sounder Instrument (MWS)

Katherine Ostojic – RAL Space – 24/10/17

Microwave Sounder (MWS)

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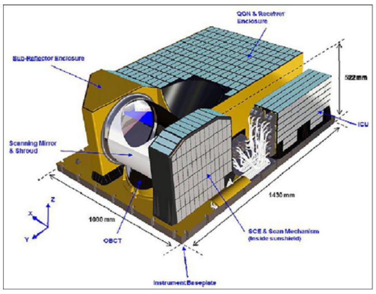
- An instrument on MetOp-SG
- Provides atmospheric temperature and humidity profiles

MetOp-SG spacecraft
http://www.esa.int/spaceinimages/Images/2012/11/MetOp_Second_Generation

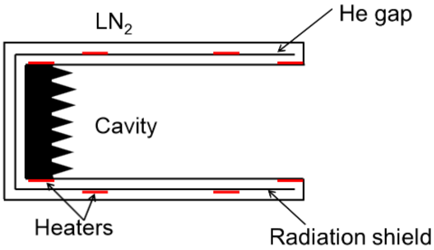


MWS instrument
http://alma-sistemi.com/?p=145

Calibration Target

- A microwave instrument calibration target for ground based testing
- RF engineered so that absorber is close to a perfect black body
- Very precisely controlled temperature
  - 80 K → 315 K
- Temperature control using a variable pressure Helium gas gap
  - Controls thermal conductance from absorber to the LN2 jacket

Diagram credit:
Nicole Melzack
Thermal Engineer
RAL Space



Microwave Absorber

- ~40 mm thick aluminium baseplate
- Covered in >2500 pyramids
  - ~9 mm wide at base and ~40 mm high
- Aluminium pyramids conformally coated in an iron powder / epoxy absorber (1.5 mm thick)

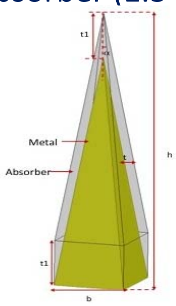


Diagram credit:
Manju Henry
RF Engineer
RAL Space

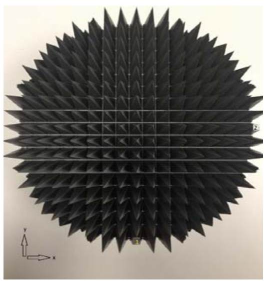


Photo credit:
Rosie Green
RF Engineer
RAL Space

Absorber Conductivity

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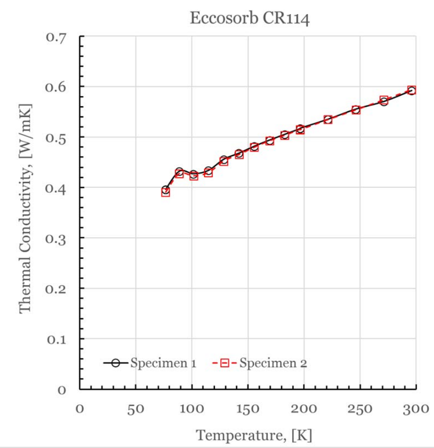
- Measured at Southampton University
- Low thermal conductivity
  - Hence a high dT in the tip of the pyramid



Graph credit:
Peter Huggard
RF Engineer
RAL Space

Requirements and Challenges

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- Need to characterise the temperature variation across the baseplate
  - Both across the width and up the pyramids
- Requirement of 0.1 K dT over the baseplate
  - Impossible due to the absorber → we have developed an alternative
- Verifying the design is tricky
  - Lots of SPRTs (standard platinum resistance thermometers), but mainly modelling

How It is Modelled

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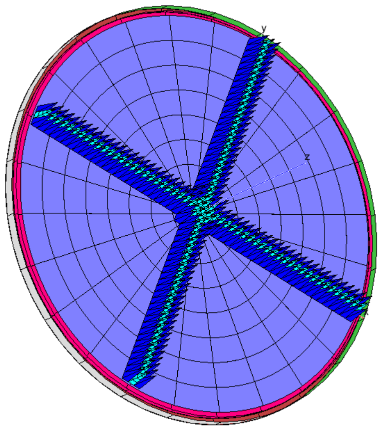
- Subset of pyramids modelled
  - Allows knowledge of variation across base
  - And keeps the radiative case fast
- Inner pyramids (teal) fully modelled
  - Manually generated conductive links
- Outer pyramids (dark blue) are purely radiative
  - Provide a representative radiative environment



Fully Modelled Pyramids

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- Manually added conductive links
  - Possible source of human error
- Low level of discretisation to save computational effort
  - BUT this underestimates the dT through the tip

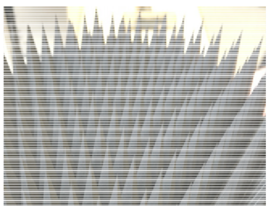
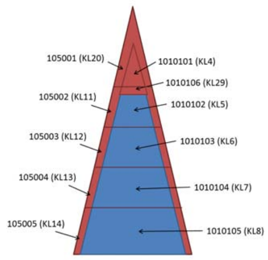


Photo credit:
Rosie Green
RF Engineer
RAL Space



ANSYS Use

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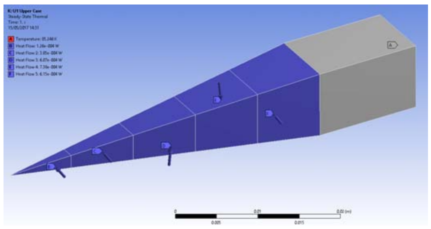
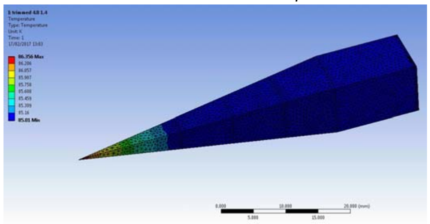
- Single pyramid modelled in FE
  - Higher discretisation
- Thermal boundary conditions taken from ESATAN-TMS model
  - Vary depending on pyramid position
- Results and node positions are used to generate brightness temperature
  - They are fed into a MATLAB code
- Constant relationship developed between the gradient and the ESATAN-TMS estimate



Modelling credit:
Joe Mann
Mechanical Engineer
RAL Space



FD vs. FE

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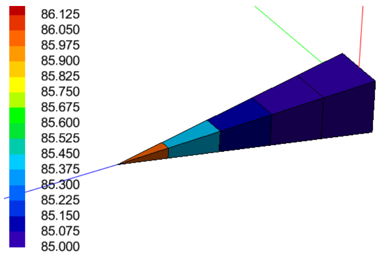
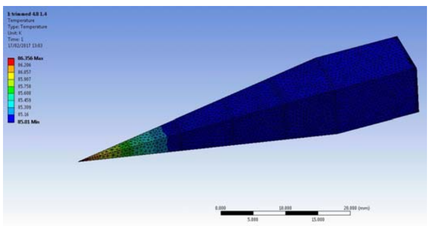
- ESATAN-TMS



- ANSYS



ESATAN-TMS vs. ANSYS

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- ESATAN-TMS modelling is used for the overall system and to provide inputs to ANSYS
  - Calculates necessary heater power to achieve set points
  - Initial PID control variables
  - Inputs to ANSYS analysis
  - Checks how fast set point transitions are
  - Ensures that other gradients are acceptable

ESATAN-TMS vs. ANSYS

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- ANSYS modelling is used to provide a more detailed pyramid analysis
  - Results used to generate a brightness temperature map of the baseplate for calibration
  - Effective variation in brightness temperature is below 0.1 K at 85K
  - Results have been used to generate a new requirement in terms of brightness temperature
    - Achievable whilst ensuring a good calibration

Lessons Learned

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- Collaborating between disciplines has helped to solve the tricky modelling challenges
  - Thermal, mechanical and RF
- 2 years in
  - It's been a steep learning curve taking on this complex model as my first project

What's next?

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- MWS Calibration Rig incorporating these blackbodies just passed CDR
- It will be manufactured in Q1/2 2018
- Verification testing will occur in Q2/3 2018

- MetOp-SG-A is due for launch in 2021

MetOp-SG Spacecraft
https://directory.eoportal.org/web/eoportal/satellite-missions/m/metop-sg


Thanks for listening
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Any questions?