Thermal Analysis of Planck HFI

16th European Workshop on Thermal and ECLS Software

ESTEC, 22-23 October 2002

Jayne Fereday
Rutherford Appleton Laboratory
j.fereday@rl.ac.uk

SUMMARY

• Planck mission overview
• Thermal design concept
• Systematic effects
• Global thermal model
• Radiative transfer model
• Thermal analysis issues
PLANCK MISSION OVERVIEW

3rd medium-sized mission of ESA’s Horizon 2000 scientific programme
Testing theories of the early universe and the origin of cosmic structure
Measuring anisotropies in the Cosmic Microwave Background - $\Delta T/T \sim 2 \times 10^{-6}$

LFI (30 - 100GHz)
Tuned radio receiver array at 20K

HFI (100 - 850GHz)
Bolometer arrays at 100mK

THERMAL DESIGN CONCEPT (1)

Passive cooling to 50/60K
• 3 v-groove shields to maximise radiation to space

JPL sorption cooler to ~20K
• cools LFI and HFI precooling stage
• thermally sunk to v-groove shields

RAL 4K JT cooler
• precooling at 18K

Dilution refrigerator to 100mK
• precooling at 1.6K
SYSTEMATIC EFFECTS

Work done as part of ESA’s Systematic Effects Working Group (SEWG)
Observations must be corrected for the effects of detector noise and layers of intervening material
Bolometer performance highly dependent on absolute temperature and temperature stability

⇒ Stringent stability requirements (e.g. bolometers < 19 nK.Hz⁻⁰.⁵)
⇒ System level analysis needed – detailed understanding of fluctuations
⇒ Interaction between instruments, spacecraft and coolers is complex
⇒ End to end modelling vital
⇒ Global thermal model created
⇒ Used to assess stability issues by providing full feedback loops to all spacecraft elements
GLOBAL THERMAL MODEL

HFI (RAL)

 Cooler interfaces

 LFI (LFI)

 Shields

 Waveguides and struts

 SVM (Alcatel)

 Solar array

 Space loads

 Harness

Sources of Instability

Operational environment
  • L2 position and orbit - scanning/spin

Coolers
  • Sorption cycling
  • JT instabilities
  • Effect of JT getter temperature being raised

General
  • Electronics switching
  • Influence of 3rd V-groove temperature on LFI
  • Influence of LFI temperature on HFI

Combined effects

Stability of sorption cooler identified as largest source
AIM: To produce a modelled detector output, including noise, to be used for the “removal of systematic effects”

INPUTS: Simulated sky Time Ordered Data (TOD)
TOD of the thermal variations of critical nodes in the HFI.

Model received showing bolometer performance against thermal behaviour
• supplied in MathCAD format
• produces bolometer output power, taking into account system noise
• originally took constant temperature as an input
• modified to accept arrays of thermal fluctuation data

Excel used originally
• MathCAD add-in
• macros used to feed thermal model output data into model
• run time and file size became restrictive very quickly

MathCAD model re-written in C++
C++ command line model now used that enables sky data and thermal data files to be input in batches
Detected Model Sky at 100GHz with Stable 4K

Power on Detector from Temp Fluctuations and ‘Constant’ Sky

Detected Model Sky at 100GHz with Temperature Fluctuations
Run time
- Sorption cooler data sets 40,000s
- 1/3s data output required
- Convergence criteria must be high
- Constants material properties used where possible
- Nodes set to boundary temperatures where possible

Format compatibility
- Thermal model in ESATAN – output to .csv files
- Sky TOD in FITS format
- Bolometer model in MathCAD

Configuration control
- Several different models required – cooldown, cooler failure cases, stability cases
- $INCLUDE$ function used whenever possible to ensure model update is easy – ‘plug in’ modules