Optical testing

Bruno Maffei
Parameters needed from optical test

• Transmission / Gain
  – Possibly of each component
  – For sure for all integrated pixels
  – Sensitivity
  – Spectral response

• Main Beams
  – Full map for all pixels
  – Variation with frequency within band
  – X-pol main beam maps

• Far sidelobes
  – Ideally over $4\pi$ steradian
  – Check for contamination
Optical tests performed on Planck (and more generally on CMB experiments)

- Transmission at component and/or instrument level
  - HFI
    - Use of Fourier Transform Spectrometer on some horns, all filters, all integrated pixels and on full instrument.
    - Use of calibration source on overall instrument to measure sensitivity across integrated spectral bands.
  - LFI
    - Use of Vector Network Analyser on components and integrated detection chains
    - Tests with loads of variable temperature
Planck Telescope: verification

- Mechanical alignment
- Photogrammetry
- Specific RF component added on FPU for ground tests
  - Extra horn + diode at 320 GHz (RTH)

Fig.3. The 320 GHz Reference Test Horn in Planck’s Focal Plane
Beam characterisation for Planck

- Measurement of all horns (beam cuts)
- Telescope beams **not** measured for all pixels (ground) RFQM / RFFM
  - One “pixel” for each band up to 320 GHz
Far sidelobes characterisation for Planck (RFQM)

Comparison between simulations and measurements

Measured

Simulated
Far sidelobes characterisation for Planck (RFQM)

Comparison between simulations and measurements

100GHz
Peak at 61.5 dBi

320GHz
Peak at 68.4 dBi

CERN 17-20 May 2016
From Planck to CORe

• **Similarities**
  – Telescope
  – Can re-use the same technology
  – Can re-use verification / alignment procedures

• **Differences**
  – Many more pixels (10s to 1000s)
  – More spectral bands (9 to 15?)
  – Calibration needs more accuracy
    • due to increase sensitivity (x30) → need to have a better understanding of the instrument / reduce systematics
  – Different technology
    • Use of planar / lens technology with possibility of cold stop and potentially higher straylight

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Higher measurement accuracy needed

• Will need to use more accurate equipment
  – FTS and broadband (as for HFI) not enough
  – Probably need to move to VNA-like system where amplitude and phase are measured with very large dynamic range

• Will need to be performed on separate components and integrated systems

• 1000s of detectors → which testing strategy?
  – Test on samples for components?
  – Then rely on integrated tests on overall instrument?

• But at the end of the day will need to include the definitive detector (bolometer or KID)
  – Back to previous measurement system?
  – How could we improve the accuracy?
Example on waveguide coupled flat lens

<table>
<thead>
<tr>
<th>Lens 2</th>
<th>Lens 1</th>
<th>Lens 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>90GHz</td>
<td>110GHz</td>
<td>90GHz</td>
</tr>
<tr>
<td>Max Value</td>
<td>-39.8dB</td>
<td>-36.2dB</td>
</tr>
<tr>
<td>FWHM (deg)</td>
<td>21.4</td>
<td>18.4</td>
</tr>
</tbody>
</table>
Far Field / Near Field

Far field horn beam pattern with bolometer

3D EM near-field measurement with VNA

Reconstruction of far-field
Example 2: 3D near field measurement of a polyethylene lens @100GHz

P. Schemmel et al, ESA antenna 2013

Then Far Field reconstruction
FPU Technology

• 1000s of pixels → Is it realistic to use horns?
• If European technology used
  – Use of planar / lens technology with possibility of cold stop and potentially higher straylight

~15cm

How to get an accurate representative measurement?

Common filters
Band-pass filter
Detectors + lens?

Array

FPU scheme

HFI bolometric detector

Array

Few mm
Equivalent of RFQM beam measurement

- Telescope with a cold instrument in CTR?
  - Unlikely feasible by industry (Thales, Airbus space) or at a huge cost
  - Warm instrument → need to replace detector
  - Could we think of a test at Liege facility?

Design of cavity-backed sinuous antenna with baluns.
Conclusion

- Optical tests and more generally calibration will have to be thought well in advance
- Need to re-use what has been used for Planck as much as we can
- Do we need to include a test plan in the proposal?