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Contents

Abstract

In this document we present the results of the LFI REBA compressor calibration performed in Liége during the Planck cryogenic test campaign. The results of the verification are provided in this document as well.

1 Introduction

1.1 Purpose and Scope

The LFI SPU is a module of the REBA whose main purpose is to compress the scientific data acquired by the radiometers and digitized by the DAE. The data compression is a crucial feature of Planck, since its angular resolution and high data acquisition frequency forbid the transmission to Earth of the full data acquired during the mission. It is worth to note that Planck is the first CMB space mission that implements an on board software compressor.

The compressor uses a mix of high-level techniques that reduce the data size by discarding information that is either not scientifically relevant (e.g. at very high frequencies) or dominated by the intrinsic radiometric noise. It is therefore extremely important to calibrate the SPU so that no scientifically relevant information is discarded during the compression.

Scope of this document is to give a first quick look analysis response of REBA Tuning performed during the Planck cryogenic tests (Liége, Belgium). The REBA calibration analysis has been done on Wednesday July, 23rd 2008.

The document is divided in two sections. The first section is related to the description of the work done that is to say the description of the LFI Log Book and the description of the performed tests. The second section is the summary of the results of each test coming from both real time and offline data analysis.

1.2 Test Configuration

The test configuration used for the REBA calibration is the following:

- SCOS2K HPCCS Version ?.?.?
- LFI Gateway Version ?.?.?
- TQL ?.?.?
- LIFE OM version 3.0.6 (release date: 2008/07/22) and[1] 3.0.7 (2008/08/12).

The LFI personnel involved during the test is listed in the following table:

Role	Name	Institute	E-mail
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IOT	M. Tomasi (remote)	UniMI	`maurizio.tomasi@unimi.it`
...			

[1] Version 3.0.6 has been used during the tests in Liége to estimate the REBA parameters. Version 3.0.7 contains a number of improvements in the code used to verify the calibration of the REBA.

2 Applicable and Reference Documents

Reference Documents

[RD1] M. Maris and M. Tomasi. Metricsforthequantizationerroranddefinitionofa"fictious" σ/q. Technical Report PL-LFI-OAT-TN-055, OAT, August 2008.

[RD2] Luca Stringhetti. Tuning of REBA Scientific Parameters. Technical Report PL-LFI-PST-PT-024, INAF/IASF Bologna, November 2007.

Applicable Documents

[AD1] A. Gregorio, M. Miccolis, L. Stringhetti, and A. Zacchei. Planck LFI User Manual. Technical Report PL-LFI-PST-MA-001, University of Trieste, June 2007.

3 REBA Tuning Test Execution

3.1 Switch on LFI in nominal science (Nominal Unit)

The test has been done using the nominal unit but the results could be used also for the redundant unit.

3.1.1 Procedure/Test Sequence

3.1.2 Results and Conclusions

3.2 Data Collection with nominal N_AVERAGE in Type1

The scientific output of the radiometers is acquired in four consecutive tests in order not to overflow the telemetry budget. Each set (and consequently each `TUN` file saved by the TQL) contains the same number of radiometric channels (2×30 GHz, 3×44 GHz and 6×70 GHz). This allows to keep the same telemetry amount in every test. See table 1 for the detailed distribution of the channels among the four `TUN` tests. The scientific telemetry has been acquired in Type1 with nominal `N_AVERAGE` setting.

3.2.1 Procedure/Test Sequence

See [RD2] and [AD1].

3.2.2 Results and Conclusions

The only objective of this step was to collect data for the REBA calibration.

No unexpected event packets	PASSED
Data collected and saved on the LIFE machine	PASSED

	RCA	Channel				Test name
Set #1	#27	00	01			TUN_0109
	#24		01	10	11	
	#21	00	01	10	11	
	#22	00	01			
Set #2	#27			10	11	TUN_0110
	#24	00				
	#22			10	11	
	#23	00	01	10	11	
	#25	00	01			
Set #3	#25			10	11	TUN_0111
	#28	00	01			
	#20	00	01	10	11	
	#19	00	01			
Set #4	#28			10	11	TUN_0112
	#19			10	11	
	#18	00	01	10	11	
	#26		01	10	11	

Table 1: Distribution of the 44 LFI channels in the four tests acquired for REBA calibration.

3.3 Data Analysis and Production of the Scientific Parameter Table

3.3.1 Procedure/Test Sequence

The analysis of the four tests TUN_0109, TUN_0110, TUN_0111 and TUN_0112 has been done using the OCA2 analysis module included in LIFE 3.0.6. The commands used for the analysis have been the following:

```
tun109 = oca2 ('lama', $
               [1595483648.0, 1595486720.0], $
               [2700, 2701, 2100, 2101, 2110, 2111, $
                2200, 2201, 2401, 2410, 2411], $
               test = 'TUN_0109', /report)

tun110 = oca2 ('lama', $
               [1595487360.0, 1595490560.0], $
               [2710, 2711, 2400, 2210, 2211, 2300, $
                2301, 2310, 2311, 2500, 2501], $
               test = 'TUN_0110', /report)

tun111 = oca2 ('lama', $
               [1595491072.0, 1595493760.0], $
               [2510, 2511, 2800, 2801, 2000, 2001, $
                2010, 2011, 1900, 1901, 2600], $
               test = 'TUN_0111', /report)

tun112 = oca2 ('lama', $
               [1595494144.0, 1595496704.0], $
```

```
               [2810, 2811, 1910, 1911, 1800, 1801, $
                1810, 1811, 2601, 2610, 2611], $
               test = 'TUN_0112', /report)

results = [tun109, tun110, tun111, tun112]
results = results[sort (results.channel)]

;; Print the best REBA parameters
for i = 0, n_elements (results) - 1 do $
  print, format = '(%"%d %8.5f %8.5f %8.2f %8.5f")', $
    results[i].channel, $
    results[i].best_params.r1, $
    results[i].best_params.r2, $
    results[i].best_params.offset, $
    results[i].best_params.second_quant

;; Print compression ratios, quantization errors and data rates
for i = 0, n_elements (results) - 1 do $
  print, format = '(%"%d %5.2f %6.4f %6.4f %6.4f %8.2f")', $
    results[i].channel, $
    results[i].verification.cr, $
    results[i].verification.qe_over_rms_sky, $
    results[i].verification.qe_over_rms_ref, $
    results[i].verification.qe_over_rms_dif, $
    results[i].verification.compressed_data_rate
```

3.3.2 Results and Conclusions

After having performed the REBA calibration and verification tests, we discovered a couple of bugs in LIFE 3.0.6 which affect some of the results obtained during the tests in Liége:

1. Some of the statistical formulae used by LIFE 3.0.6 can suffer from numerical errors in some extreme cases. Luckly, this has not been the case for the Liége tests: after having corrected the code, we repeated the analysis and found that there were only a few barely noticeable changes in some of the parameters, always less than 1%. After having made these changes, LIFE has been upgraded to 3.0.7.

2. There was a bug in the code calculating the value of $(\epsilon_q/\sigma)_{\rm sky}$ and $(\epsilon_q/\sigma)_{\rm ref}$. Again, this did not affect the estimation of the REBA parameters as the optimization code only uses $(\epsilon_q/\sigma)_{\rm dif}$. This bug was corrected as well, and LIFE was upgraded to version 3.0.8.

The REBA parameters obtained in Liége with LIFE 3.0.6 are listed in table 2. The "correct" REBA parameters obtained with LIFE 3.0.8 are listed in table 3: the differences are very small (always $< 0.1\%$) and constrained to a few values of s_q.

The estimated performances for the parameters are shown in table 4. These have been calculated using LIFE 3.0.8 (in order to overcome the bug in the calculation of $(\epsilon_q/\sigma)_{\rm sky}$ and $(\epsilon_q/\sigma)_{\rm ref}$, see above).

The total data rate was 37 932 bits/s. Plots of the compression ratio, data rate and quantization errors are shown in figures 1 and 2.

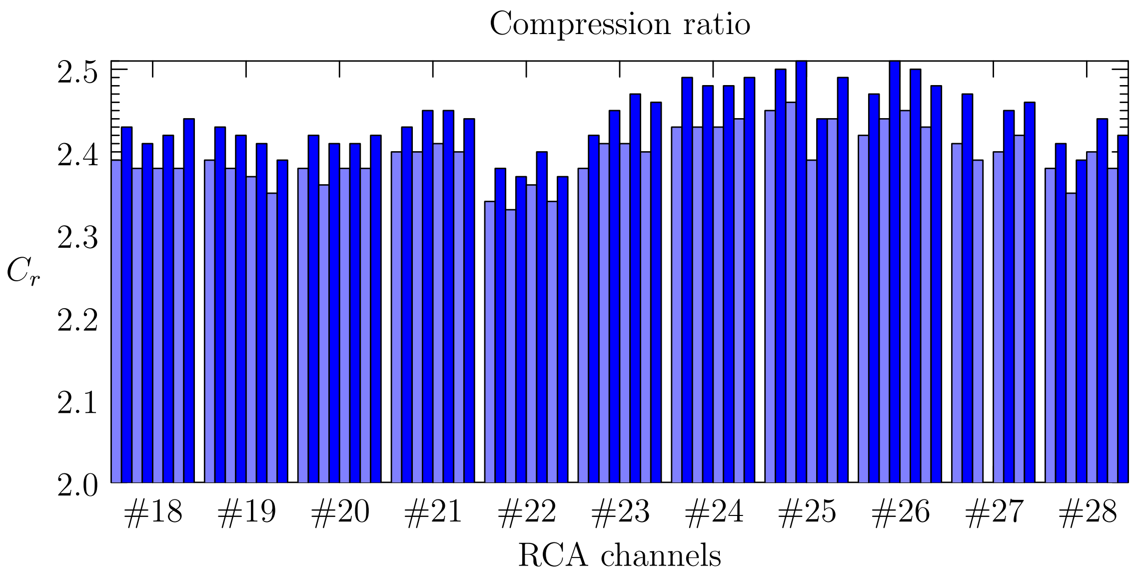

Figure 1: Compression ratio for the REBA calibration (light bars) and verification (dark bars) tests. About the reason why there is no value shown for the verification of #2701, see paragraph 4.3.

Average compression rate ≥ 2.4	PASSED
$\sigma/q \geq 2$ for every channel	PASSED
No saturations found in any channel	PASSED

The impact of the quantization on the data is estimated as the ratio between the quantization error ϵ_q and the RMS σ of the uncompressed data. The σ/q quantity usually quoted in old documents can be derived by using the relation

$$(\sigma/q)_x = \frac{\sqrt{12}}{(\epsilon_q/\sigma)_x},$$

where x can be either "sky", "ref" or "dif". However, as discussed in [**?**], the σ/q ratio is not as informative as ϵ_q/σ. Here we have therefore decided to use the latter quantity in presenting the results.

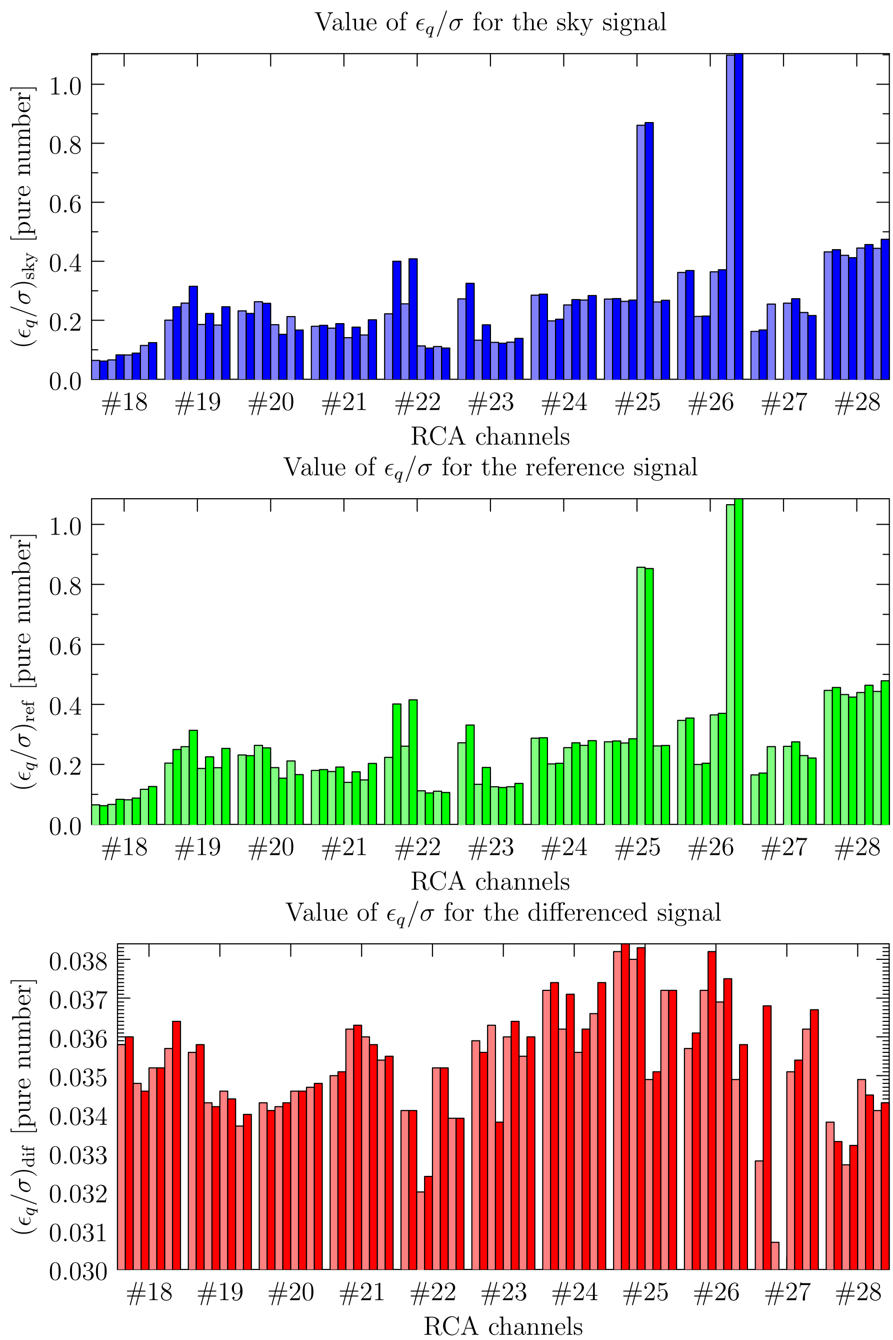

Figure 2: Ratio between the quantization error and the intrinsic RMS of the sky, reference and differenced signals for the REBA calibration (light bars) and verification (dark bars) tests. About the reason why there are no values shown for the verification of #2701, see paragraph 4.3.

Ch.	N_AVER	r_1	r_2	Δ	s_q
1800	52	1.04167	0.95833	-65.50	4.07328
1801	52	1.04167	0.95833	-50.60	3.16128
1810	52	1.04167	0.91667	-126.20	2.76549
1811	52	1.04167	0.95833	-125.90	3.65060
1900	52	1.04167	0.95833	-140.20	3.72660
1901	52	1.04167	0.95833	24.80	3.37387
1910	52	1.04167	0.95833	86.10	3.26482
1911	52	1.04167	0.95833	-111.10	2.76712
2000	52	1.04167	0.95833	-32.90	3.41267
2001	52	1.04167	0.95833	-105.20	3.13034
2010	52	1.04167	0.95833	-76.00	3.44624
2011	52	1.04167	0.95833	-87.40	3.52910
2100	52	1.04167	0.95833	31.20	4.12207
2101	52	1.04167	0.95833	-113.50	4.37668
2110	52	1.04167	0.95833	50.20	4.29292
2111	52	1.04167	0.95833	-58.60	4.04952
2200	52	1.04167	1.00000	87.70	3.68405
2201	52	1.04167	1.00000	28.52	3.34498
2210	52	1.08333	1.00000	124.12	3.08533
2211	52	1.08333	1.00000	-128.72	2.60282
2300	52	1.04167	1.00000	90.31	5.09588
2301	52	1.04167	0.95833	95.90	4.36592
2310	52	1.04167	0.95833	-3.50	4.58472
2311	52	1.04167	0.95833	-61.10	4.09794
2400	88	1.04167	0.91667	-148.10	4.37509
2401	88	1.08333	0.87500	-151.73	3.37432
2410	88	1.04167	0.91667	-123.90	4.48988
2411	88	1.04167	0.91667	-73.18	4.82731
2500	88	1.04167	0.91667	-149.17	6.35060
2501	88	1.04167	0.91667	-79.85	6.69850
2510	88	1.00000	0.95833	-13.75	5.69803
2511	88	1.04167	0.91667	-44.38	5.28898
2600	88	1.00000	0.91667	-42.31	4.57143
2601	88	1.04167	0.87500	-94.48	4.82428
2610	88	1.04167	0.91667	-42.26	5.86638
2611	88	1.00000	0.95833	-8.78	7.49587
2700	126	1.04167	0.83333	-159.40	3.09905
2701	126	1.00000	0.87500	-62.42	2.92967
2710	126	1.00000	0.87500	-120.98	3.29936
2711	126	1.04167	0.87500	-147.32	3.43767
2800	126	1.08333	1.00000	-50.57	3.63361
2801	126	1.08333	1.00000	-43.63	2.98412
2810	126	1.04167	0.95833	1.10	4.12997
2811	126	1.04167	0.95833	-28.80	3.58258

Table 2: The table of REBA parameters produced by LIFE 3.0.6. These have been the parameters used for the REBA verification tests `XXX_0196` and `XXX_0197`.

Ch.	r_1	r_2	Δ	s_q
1800	1.04167	0.95833	-65.50	4.07493
1801	1.04167	0.95833	-50.60	3.16113
1810	1.04167	0.91667	-126.20	2.76560
1811	1.04167	0.95833	-125.90	3.65056
1900	1.04167	0.95833	-140.20	3.72623
1901	1.04167	0.95833	24.80	3.37356
1910	1.04167	0.95833	86.10	3.26477
1911	1.04167	0.95833	-111.10	2.76703
2000	1.04167	0.95833	-32.90	3.41248
2001	1.04167	0.95833	-105.20	3.13067
2010	1.04167	0.95833	-76.00	3.44607
2011	1.04167	0.95833	-87.40	3.52918
2100	1.04167	0.95833	31.20	4.12178
2101	1.04167	0.95833	-113.50	4.37680
2110	1.04167	0.95833	50.20	4.29263
2111	1.04167	0.95833	-58.60	4.05021
2200	1.04167	1.00000	87.70	3.68313
2201	1.04167	1.00000	28.52	3.34534
2210	1.08333	1.00000	124.12	3.08525
2211	1.08333	1.00000	-128.72	2.60317
2300	1.04167	1.00000	90.31	5.09559
2301	1.04167	0.95833	95.90	4.36558
2310	1.04167	0.95833	-3.50	4.58462
2311	1.04167	0.95833	-61.10	4.09753
2400	1.04167	0.91667	-148.10	4.37567
2401	1.08333	0.87500	-151.73	3.37465
2410	1.04167	0.91667	-123.90	4.48990
2411	1.04167	0.91667	-73.18	4.82749
2500	1.04167	0.91667	-149.17	6.34959
2501	1.04167	0.91667	-79.85	6.69817
2510	1.00000	0.95833	-13.75	5.69808
2511	1.04167	0.91667	-44.38	5.28843
2600	1.00000	0.91667	-42.31	4.57164
2601	1.04167	0.87500	-94.48	4.82411
2610	1.04167	0.91667	-42.26	5.86694
2611	1.00000	0.95833	-8.78	7.49693
2700	1.04167	0.83333	-159.40	3.09913
2701	1.00000	0.87500	-62.42	2.92980
2710	1.00000	0.87500	-120.98	3.29916
2711	1.04167	0.87500	-147.32	3.43770
2800	1.08333	1.00000	-50.57	3.63367
2801	1.08333	1.00000	-43.63	2.98409
2810	1.04167	0.95833	1.10	4.13365
2811	1.04167	0.95833	-28.80	3.58255

Table 3: The new table of REBA parameters produced by LIFE 3.0.8. Note the similarity with table 2. These parameters have *not* been used during the tests in Liége, since LIFE 3.0.8 has been released after they were completed.

Ch.	C_r	$(\epsilon_q/\sigma)_{\rm sky}$	$(\epsilon_q/\sigma)_{\rm ref}$	$(\epsilon_q/\sigma)_{\rm dif}$	[bits/sec]
1800	2.39	0.0640	0.0651	0.0358	1101.00
1801	2.38	0.0657	0.0665	0.0348	1108.18
1810	2.38	0.0825	0.0819	0.0352	1107.41
1811	2.38	0.1146	0.1169	0.0357	1105.11
1900	2.39	0.2005	0.2042	0.0356	1105.92
1901	2.38	0.2583	0.2590	0.0343	1110.33
1910	2.37	0.1858	0.1864	0.0346	1110.26
1911	2.35	0.1839	0.1889	0.0337	1120.00
2000	2.38	0.2319	0.2313	0.0343	1109.71
2001	2.36	0.2629	0.2634	0.0342	1115.18
2010	2.38	0.1851	0.1892	0.0346	1109.13
2011	2.38	0.2125	0.2114	0.0347	1108.95
2100	2.40	0.1797	0.1799	0.0350	1101.33
2101	2.40	0.1734	0.1762	0.0362	1097.53
2110	2.41	0.1410	0.1401	0.0360	1096.52
2111	2.40	0.1502	0.1482	0.0354	1100.24
2200	2.34	0.2220	0.2234	0.0341	1124.72
2201	2.33	0.2558	0.2607	0.0320	1130.12
2210	2.36	0.1132	0.1119	0.0352	1116.03
2211	2.34	0.1110	0.1106	0.0339	1125.80
2300	2.38	0.2726	0.2719	0.0359	1108.24
2301	2.41	0.1326	0.1336	0.0363	1096.61
2310	2.41	0.1252	0.1254	0.0360	1093.80
2311	2.40	0.1259	0.1254	0.0355	1098.19
2400	2.43	0.2852	0.2874	0.0372	641.62
2401	2.43	0.1980	0.2015	0.0362	642.29
2410	2.43	0.2521	0.2558	0.0356	642.09
2411	2.44	0.2686	0.2634	0.0366	639.94
2500	2.45	0.2720	0.2752	0.0382	636.25
2501	2.46	0.2642	0.2713	0.0380	635.60
2510	2.39	0.8610	0.8571	0.0349	651.52
2511	2.44	0.2622	0.2615	0.0372	638.38
2600	2.42	0.3621	0.3467	0.0357	645.54
2601	2.44	0.2130	0.1997	0.0372	637.51
2610	2.45	0.3643	0.3649	0.0369	636.86
2611	2.43	1.0986	1.0655	0.0349	642.28
2700	2.41	0.1623	0.1649	0.0328	450.75
2701	2.39	0.2549	0.2592	0.0307	455.54
2710	2.40	0.2581	0.2602	0.0351	454.28
2711	2.42	0.2264	0.2294	0.0362	450.01
2800	2.38	0.4319	0.4467	0.0338	457.85
2801	2.35	0.4202	0.4328	0.0327	462.88
2810	2.40	0.4449	0.4396	0.0349	453.76
2811	2.38	0.4439	0.4432	0.0341	456.75

Table 4: The estimated performances of the REBA compressor calculated by LIFE 3.0.8 during the calibration phase. C_r is the compression ratio, ϵ_q/σ is the ratio between the quantization error and the intrinsic RMS of the sky, reference and differenced signal. The last column provides the number of bits per second produced by the REBA.

4 REBA Verification Test Execution

4.1 Switch on LFI in Nominal Science

4.1.1 Procedure/Test Sequence

4.1.2 Results and Conclusions

4.2 Data Collection with nominal N_AVERAGE in Type5

4.2.1 Procedure/Test Sequence

4.2.2 Results and Conclusions

The data have been acquired in two separate tests because of a communication failure. The two tests are XXX_0196 and XXX_0197. All the RCAs but #18 and #26 have been analysed using the former.

4.3 Data Analysis

4.3.1 Procedure/Test Sequence

The two tests XXX_0196 and XXX_0197 have been analyzed using the following IDL procedures with LIFE 3.0.7:

```
pro analyse_reverie_channel, lun, channel, test = test

    compile_opt idl2

    result = lama_reverie (channel, test = test)
    for cur_ch = 0, n_elements (result) - 1 do begin
        if ~ptr_valid (result[cur_ch]) then $
            continue

        cur_struct = *(result[cur_ch])

        printf, lun, format = '(%"%02d%02b %5.2f %7.4f %7.4f %7.4f")', $
            cur_struct.feed_horn, cur_struct.channel, $
            mean (cur_struct.compression_rates), $
            cur_struct.qe_over_rms_sky, $
            cur_struct.qe_over_rms_ref, $
            cur_struct.qe_over_rms_dif

        ptr_free, result[cur_ch]
    endfor

    result = 0
end

pro analyse_reverie_test, test

  compile_opt idl2
```

```
  file_name = string (format = '(%"reverie_%s.dat")', test)
  openw, lun, file_name, /get_lun
  for cur_fh = 18, 28 do begin
      analyse_reverie_channel, lun, cur_fh, test = test
  endfor
  free_lun, lun
  print, format = '(%"Results saved in file %s")', file_name
end
```

The `analyse_reverie_test` procedure analyses the specified test and saves the results in a file named `reverie_NNN.dat`, where `NNN` is the name of the test, e.g. `reverie_XXX_0196.dat`.

The analysis has been performed using the following commands:

```
analyse_reverie_test, 'XXX_0196', [19, 20, 21, 22, 23, 24, 25, 27, 28]
analyse_reverie_test, 'XXX_0197', [18, 26]
```

The results are shown in table 5. Note that the requirement on the compression ratio is satisfied for every frequency band, since $C_r = 2.417$ for 70 GHz, $C_r = 2.487$ for 44 GHz and $C_r = 2.434$ for 30 GHz (excluding #2701).

Ch.	C_r	$(\epsilon_q/\sigma)_{\rm sky}$	$(\epsilon_q/\sigma)_{\rm ref}$	$(\epsilon_q/\sigma)_{\rm dif}$
1800	2.43	0.0618	0.0623	0.0360
1801	2.41	0.0827	0.0835	0.0346
1810	2.42	0.0887	0.0877	0.0352
1811	2.44	0.1242	0.1262	0.0364
1900	2.43	0.2457	0.2496	0.0358
1901	2.42	0.3151	0.3136	0.0342
1910	2.41	0.2231	0.2251	0.0344
1911	2.39	0.2458	0.2532	0.0340
2000	2.42	0.2232	0.2291	0.0341
2001	2.41	0.2575	0.2550	0.0343
2010	2.41	0.1523	0.1540	0.0346
2011	2.42	0.1670	0.1660	0.0348
2100	2.43	0.1828	0.1826	0.0351
2101	2.45	0.1886	0.1911	0.0363
2110	2.45	0.1768	0.1751	0.0358
2111	2.44	0.2017	0.2031	0.0355
2200	2.38	0.4000	0.4013	0.0341
2201	2.37	0.4084	0.4151	0.0324
2210	2.40	0.1058	0.1047	0.0352
2211	2.37	0.1059	0.1063	0.0339
2300	2.42	0.3253	0.3311	0.0356
2301	2.45	0.1846	0.1898	0.0338
2310	2.47	0.1222	0.1230	0.0364
2311	2.46	0.1386	0.1365	0.0360
2400	2.49	0.2885	0.2887	0.0374
2401	2.48	0.2036	0.2036	0.0371
2410	2.48	0.2701	0.2718	0.0362
2411	2.49	0.2838	0.2791	0.0374
2500	2.50	0.2735	0.2780	0.0384
2501	2.51	0.2685	0.2852	0.0383
2510	2.44	0.8701	0.8528	0.0351
2511	2.49	0.2678	0.2630	0.0372
2600	2.47	0.3686	0.3544	0.0361
2601	2.51	0.2143	0.2038	0.0382
2610	2.50	0.3713	0.3702	0.0375
2611	2.48	1.1038	1.0855	0.0358
2700	2.47	0.1642	0.1669	0.0371
2701	—	—	—	—
2710	2.45	0.2574	0.2611	0.0355
2711	2.46	0.2230	0.2287	0.0364
2800	2.41	0.4393	0.4563	0.0333
2801	2.39	0.4122	0.4243	0.0332
2810	2.44	0.4566	0.4638	0.0345
2811	2.42	0.4745	0.4786	0.0343

Table 5: Results of the REBA verification phase. The #2701 channel could not be analyzed as the r_2 parameter was mistakenly set to 0.082 instead of 0.82 during the acquisition of the `XXX_0196` and `XXX_0197` tests (see table 2).