Publication Year	2011
Acceptance in OA	2023-02-14T16:47:36Z
Title	LFI in-flight susceptibility to Front End electric instabilities: analysis of the HK over-sampling Test
Authors	CUTTAIA, FRANCESCO
Handle	http://hdl.handle.net/20.500.12386/33459
Volume	PL-LFI-PST-TN-100

TITLE: LFI in-flight susceptibility to Front End electric instabilities: analysis of the HK over-sampling Test

DOC. TYPE: TECHNICAL NOTE

PROJECT REF.: PL-LFI-PST-TN-100 **PAGE:** 1, 15

ISSUE/REV.: 1.0 **DATE:** December 2011

Prepared by	F. CUTTAIA LFI System Team	Date: December 9th, 2011 Signature:
Agreed by	C. BUTLER LFI Program Manager	Date: December 9th, 2011 Signature: R.C. Butler
Approved by	N. MANDOLESI LFI Principal Investigator	Date: December 9th, 2011 Signature:

DISTRIBUTION LIST

Recipient	Company / Institute	E-mail address
J. TAUBER	ESA – Noordwijk	Jan.Tauber@esa.int
N. MANDOLESI	IASF/INAF – Bologna	mandolesi@iasfbo.inaf.it
C. BUTLER	IASF/INAF – Bologna	butler@iasfbo.inaf.it
M. BERSANELLI	UNIMI – Milano	Marco.bersanelli@mi.infn.it
A. GREGORIO	INFN - Trieste	Anna.Gregorio@ts.infn.it
A. MENNELLA	UNIMI – Milano	Aniello.Mennella@fisica.unimi.it
A. ZACCHEI	INAF - OA Trieste	zacchei@oats.inaf.it
LFI Systematic		lfi_systematics@iasfbo.inaf.it
RPM	ESA – Noordwijk	planck_rpm@rssd.esa.int
LFI- Operations		lfi-operations@oats.inaf.it
G. MORGANTE	IASF/INAF – Bologna	morgante@iasfbo.inaf.it

CHANGE RECORD

Issue	Date	Sheet	Description of Change	Release
Issue 1.0	Dec '11	All	first issue of document	1.0

SUMMARY

1. INTRODUCTION

Drain Currents are the unique HK parameter monitoring the electric behavior of the LFI Front End LNAs. Their importance is related with their capability to track gain changes at Front-End level induced by Gate Voltage (Vg) and Drain Voltage (Vd) changes. In fact, Vg and Vd are not measured but only indirectly known from the values set at DAE level any time the DAE actual TM packet is commanded (once per pointing period). The baseline sampling frequency is 0.0156 Hz (every 64 ‘’) . Higher sampling could allow to:

- Track Scientific Voltage signal instabilities due to spikes or changes in the LNAs power. It is very powerful to recognize such anomalies and to help in flagging bad or suspicious data.
- Characterize the Electric susceptibility in order to possibly remove its effect from total power or differential data.

The effectiveness of removal techniques is tightly related with the sampling frequency (SF) . In fact:

- the correlation coefficients depend on the available statistics (increasing with SF)
- The goodness of removal depends on the ratio of the HK and SCI data SF. The closer is the HK sampling frequency to SCI data frequency, the smaller is the quantization effect (due to HK interpolation to match the HK frequency) introduced by the removal in SCI data.

2. ANALYSIS

The analysis is based on two input data ranges:

A. RANGE 1: Data from the 1 hour dedicated Test (HK-TEST) performed on October 2011 the 19th (starting at 12.00 UTC): Id HK were acquired at 1Hz.

B. RANGE 2: Data from twenty days survey (containing also RANGE 1 to increase the number of points) : Ids are nominally sampled at 0.0156 Hz (apart during RANGE 1) .

A. RANGE 1 was used to compare between data differently sampled: in fact, in post processing, HK sampled at 1Hz were down-sampled to 0.125 Hz (1 sample every 8 seconds) and to 0.0156 Hz (1 sample every 64 ''). The 0.125 Hz frequency have been chosen as it was believed possibly compatible with instrumental capabilities. This analysis was aimed at demonstrating that:

   The SCI data dependence on the drain currents is as much correlated as the sampling frequency is higher (the correlation coefficient was used as estimator)

   In the case of correction of the gain changes caused by electric instabilities (through the model resulting from point a.) , the accuracy of results is proportional to SF. This is due to that the increasing SF minimizes the quantization effects introduced when HK are resampled (over-sampling) to the SCI data frequency before the model correction .

B. RANGE 2 was used to :

   Get more accurate susceptibility coefficients (correlating more than 30.000 samples instead of only 3600 from the HK Oversampling Test).

   Apply correction (from coefficients calculated in a.) to a large data sample paying special attention to Total Power data: in fact, reference load signal instabilities higher than those induced by the 4K reference Load thermal instabilities allow to track the LNAs Gain fluctuations. Despite of this technique is still under evaluation, it seems to be a promising calibration tool. For each detector,

EQ (1) $DV/V = [(Vref - \langle Vref \rangle) / \langle Vref \rangle]$ and $GMF = \langle Vsky \rangle / \langle Vref \rangle$

   were calculated on one hour base (approximately corresponding to a pointing period) ; the sigma comparison (before / after correction) was used as estimator. It is worth noting that *GMF* was calculated without applying any dipole model removal to Sky data, hence some residual effect will remain also at the end of the cleaning process.

3. MODEL

Correlation was calculated both from Total power data and from differenced data. In order to get the best correlation, only synchronous data streams have been considered: in fact the different sampling rate of HK and SCI data requires that SCI data were down-sampled to the HK frequency. Technically, SCI data corresponding to the two closer times before and after the HK time were interpolated, to get the best approximation of the value synchronous with the recorded HK. SCI data interpolation introduces an error very small, advantaging of the much higher sampling frequency of SCI telemetry respect to the HK .

The linear Pearson correlation coefficient of the two vectors [SCI data (sky, Ref or diff) , HK data (*IdP*)] was calculated: *IdP* is a linear combination of the Drain Currents (Id1, Id2) powering the two coupled LNAs. In fact, due to the pseudo-correlation architecture of the LFI LNAs, the two coupled LNAs contribute to the total Gain G in reason of their individual Gain (and of the other unbalancing in the two lines): the optimal case would be G1 = G2, with perfectly balanced lines, corresponding to condition P=0.5. Hence, the *P-value* weighting the two Id contributions was kept as free running parameter [from 0 to 1, stepped by 0.05].

Ordinary least-square linear fit was applied to estimate the two unknown parameters (offset β and slope α) in the linear regression :

EQ (2) $\text{SCI data} = \alpha \cdot [\, P \cdot Id1 + (1-P) \cdot Id2 \,] + \beta$ SCI data can be: sky, ref or DIFF [see B.EQ (3)].

Diff data are calculated from total power data, calculating one Gain Modulation Factor per hour.

EQ (3) $DIFF = Vsky - GMF \cdot Vref \,, \; GMF = [<Vsky> / <Vref>]_{1h}$

Once found the triplet (α, β,P) for each channel (Sky, Ref , Diff) , data correction was performed in two ways:

<u>Operating on Total power data</u> :

EQ (4) $Sky/Ref_{corr} = Sky/Ref - \alpha_{S/R} \cdot [\, P_{S/R} \cdot Id1 + (1-P_{S/R}) \cdot Id2 \,] + \beta_{S/R} + Sky(0)/Ref(0)$

<u>Operating on diff data (Direct method)</u> :

EQ (5) $Diff_{corr} = Diff - \alpha_{S/R} \cdot [\, P_D \cdot Id1 + (1-P_D) \cdot Id2 \,] + \beta_D + Diff(0)$

<u>Operating on Sky $_{corr}$ /Ref $_{corr}$</u> (Indirect method) :

EQ (6) $Diff^*_{corr} = Vsky_{corr} - GMF \cdot Vref_{corr} \,, \; GMF = [<Vsky_{corr}> / <Vref_{corr}>]_{1h}$

<u>The goodness of correction (Δ)</u>, in all the cases above, was measured by comparing the standard deviation of SCI data before and after correction:

EQ (7) $\Delta = \text{sigma}(SCI_{corr}) - \text{sigma}(SCI)$

4. RESULTS:

4.1 TOTAL POWER ANALYSIS

Some channels show a strong correlation of total power data with Id HK. In particular, due to that the output from each of the back end coupled diodes is amplified by the two coupled LNAs, the maximum correlation can be obtained when considering an opportunely weighted average of the two drain currents powering the two LNAs. Hence , for each diode, they were calculated:

- The correlation (drain current- SCI data) , and the linear coefficients [EQ (2)B.EQ (2)], for any of the 21 weight (p) values ranging from 0 to 1 in steps of 0,05. It was done for each Sky and Ref voltage.(Figure 1)
- The p-value maximizing correlation for each Sky and Ref.
- The sigma [B.EQ (7)] from total power data before and after Model removal. Results were crosschecked with those from the previous step, to be confident that removal was able to provide optimal results corresponding to the optimal p-values. Plots of the sigma improvement (after correction) versus correlations for any detector and weight shows that: i) the correction is powerful , ii) improvement is proportional to the correlation coefficient. (Figure 2).
- The DV/V before and after removal (Figure 3, left panel). [EQ (1)]
- The GMF factor before / after removal (Figure 3, right panel). [EQ (6)]

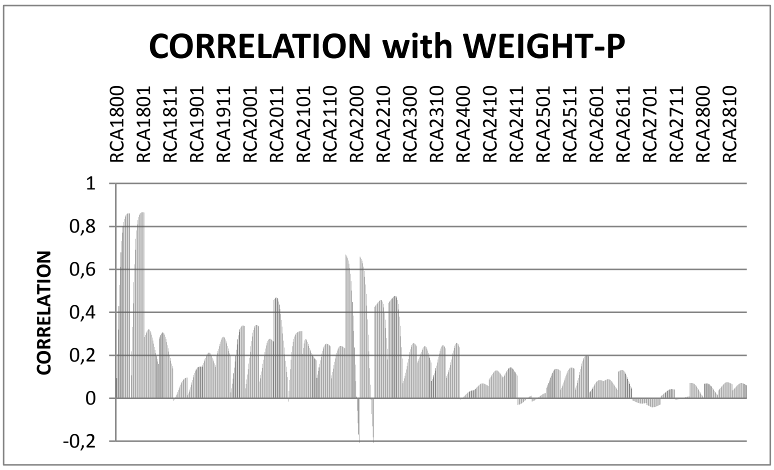

Figure 1 Linear correlation coefficient variation versus channels. Each bar is obtained stacking all the possible correlation values obtained for that channel changing the weight 'p' (causing the smoothed shape of bars)

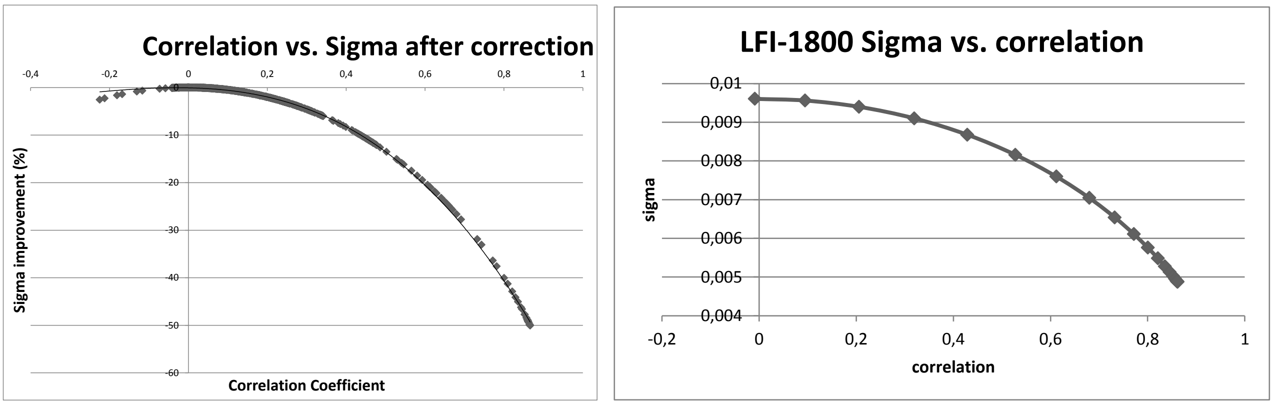

Figure 2 Left panel: Sigma (Y axis) improvement after correction versus Correlation coefficient. All channels are stacked in the same data set , for any of the p values. Negative correlations correspond to anti-correlated behaviors. Right panel: Sigma versus correlation (LFI1800) . The different points are obtained by changing the P-weight values from 0 to 1.

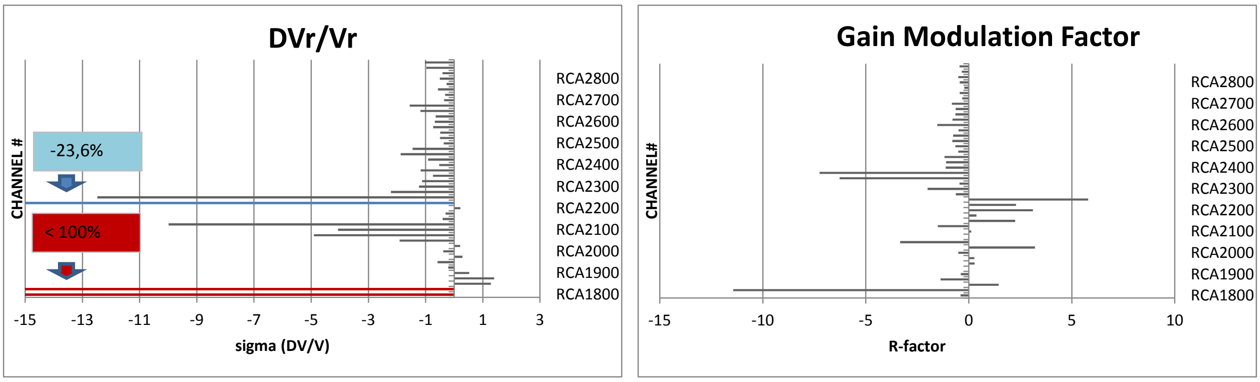

Figure 3 Improvement in DV/V sigma % (reference load) after total power correction (left panel): LFI 18 M (00-01), red bars , and LFI 22, light blue bars, show the largest effect; Other channels ,such as LFI20S and LFI21M, show evident effects from removal. On the right panel, Gain modulation factor sigma % comparison before and after removal. Results, depending here both on Sky and Ref signals, demonstrate that it is possible to get a good improvement for some channels while other worsen after removal. (Channels are grouped following the sequence 00-01-10-11)

Example of successful corrections to total power data, producing a sensitive improvement in the DV/V term stability, are displayed in Figure 4

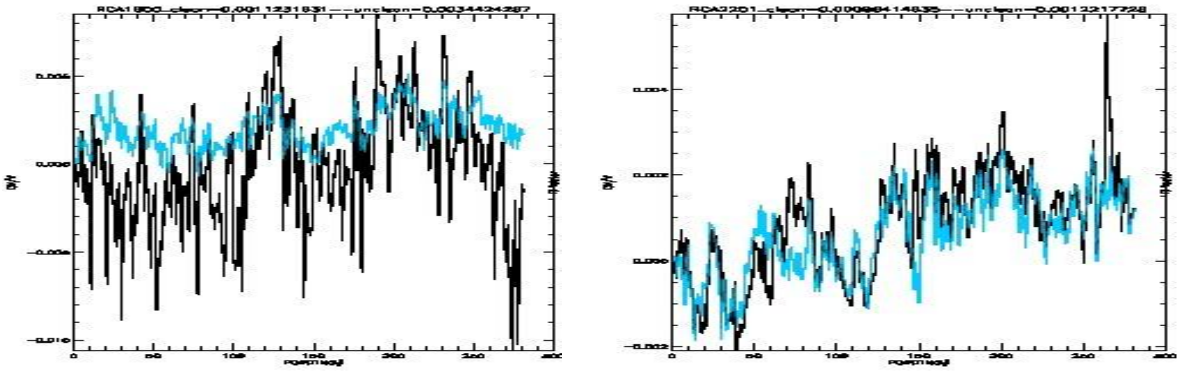

Figure 4 DV/V calculated along 300 pointing periods for channels LFI 18-00 (left panel) and LFI 22-01 (right panel). Black lines correspond to raw data. cyan lines to corrected data. In LFI18-00 sigma (DV/V) changes from 0.00034 to 0.0011, while for LFI22-01 changes from 0.0012 to 0.0009

4.2 DIFFERENTIAL DATA ANALYSIS

The two different models discussed in §3 were applied to evaluate the effect of correction on differenced data. The two cases are analyzed hereafter.

4.2.1 Data Diff correction (Indirect)

As already shown by the R-factor analysis, the effect traced by Id changes mostly reflects in LNAs Gain changes, affecting in a similar way both Sky and Ref signals. This implies that results from data correction are not as evident as on Total power data (demonstrating that the pseudo-correlation scheme of radiometers works properly). However, several channels show (Figure 5, left panel) improvements larger than 0.003 (and two larger than 0.005) , amounts not negligible when considering diff data. Good HK - SCI data correlations at total power level reflect not always clear sigma improvements in diff data after correction (evident in LFI1800 and LFI1801, both strongly correlated (>0.8)) at Total power level but producing respectively null or good (≈ 0.6 %) improvements (Figure 5 right panel).

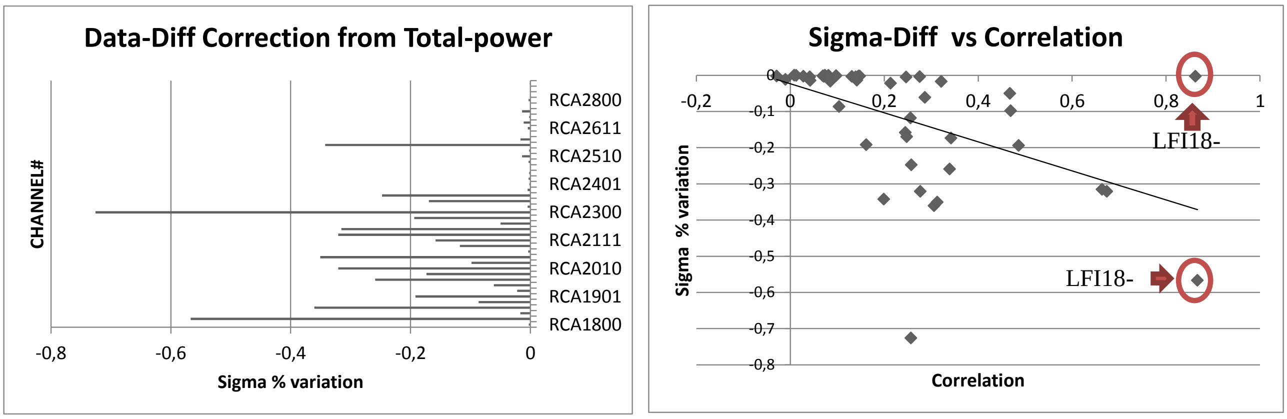

Figure 5 Left panel: Sigma variation after correction. (Channels are grouped following the sequence 00-01-10-11) . Right panel: Sigma improvement calculated on diff data versus Correlation at total power level data. Highlighted by red circles the two different behaviors of LFI18-00 and LFI18-01.

4.2.2 Data Diff correction (Direct)

Despite of the very low correlation coefficients resulting from HK- Diff Data correlation, the susceptibility direct model applied to diff data produces for some channels improvements of the same order of the indirect model (Figure 6, left panel) . The very difference is in that, in this last case, the correspondence between the sigma improvement following correction and the correlation coefficient is here evident, as shown by Figure 6, right panel: about all points lie on a continuous curve.

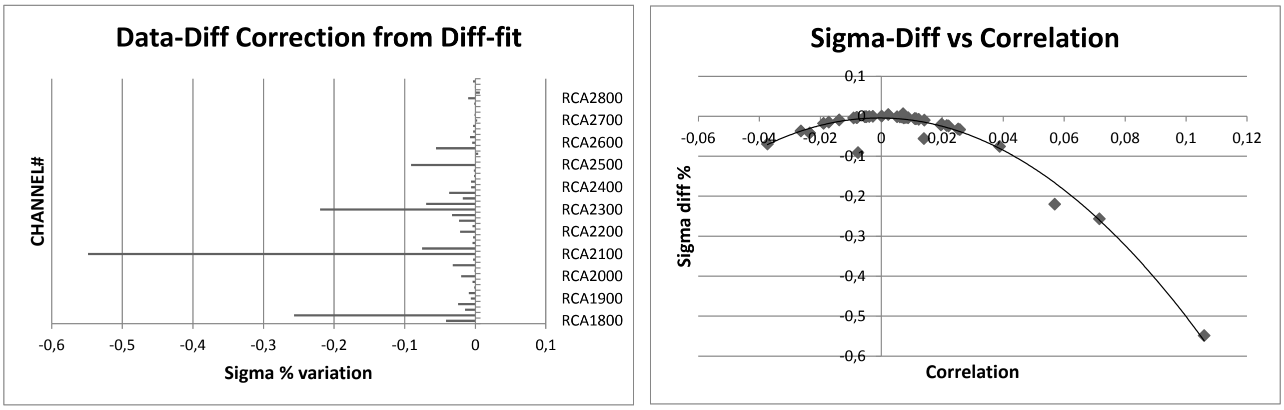

Figure 6 Left panel: Sigma variation after correction on diff data. (Channels are grouped following the sequence 00-01-10-11) . Right panel: Sigma improvement calculated on diff data versus Correlation. Points lie on a continuous curve.

It is important to notice that, for this analysis, data were not cleaned before from other effects (the most are generated by thermal changes and maneuvers), hence it is expected that a most accurate analysis, performed starting from cleaned data, and based on longer data streams accounting only for the effective observation time and discarding flagged data, could provide much more correlated results. Also in this case, the p-weighted analysis performed correlating diff data to linear combinations of Id1,Id2 HK, shows the capability to simultaneously optimizing correlation coefficients and sigma improvements, as shown by the two example proposed in Figure 7

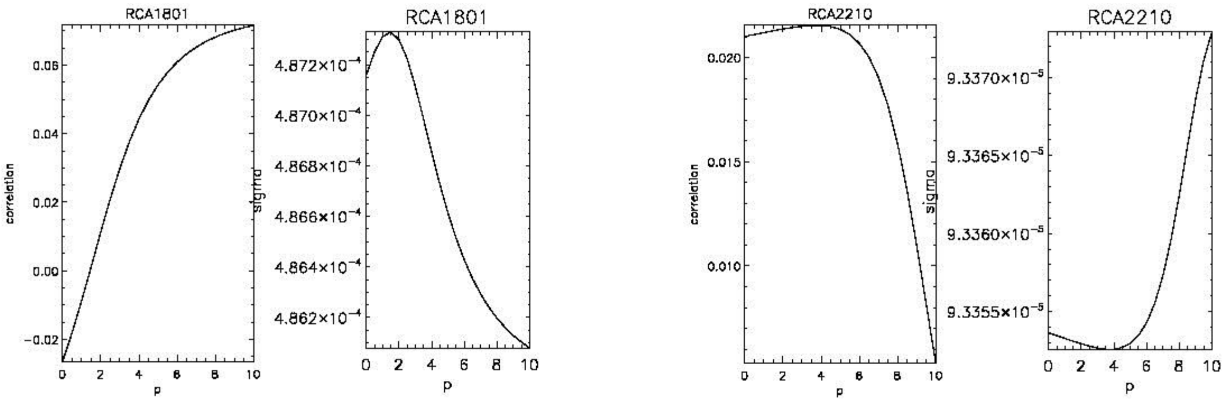

Figure 7 For each channel (LFI 1801 , first and second; LFI 2210, third and fourth panels) they are represented: DIFF DATA – Id HK Correlation with varying p-weight (first and third panels); Sigma Diff with varying p-weight (second and fourth panels). P assumes 21 values from 0 to 1 in steps of 0.05 (the x axis scale must be multiplied times 0.1). Plots show that the p-value optimizing correlation is the same providing the best sigma after correction.

4.3 EFFECTS OF HK OVERSAMPLING

The correlation from data acquired at the nominal HK sampling frequency (0.0156Hz) increases, as expected, with the SF (see the synoptic comparison between 1h data and 10 days data in Figure 8 and the example reported in Figure 9, where data sampled at different frequencies during the same time range are compared) . Moreover, the accuracy of removal (sigma change used as estimator) increases with the HK sampling frequency (see Figure 10). This is mainly due to two factors: i) the larger accuracy in the linear coefficients calculation ii) the lower quantization effect introduced when the HK are oversampled to match the SCI data frequency (Figure 11 and Figure 12)

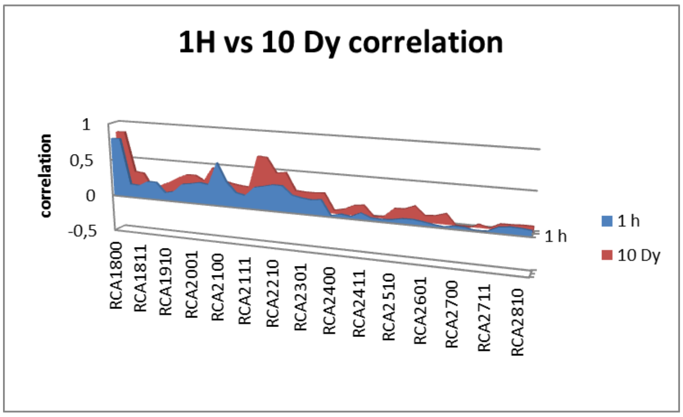

Figure 8 Id HK – SCI data correlation: comparison between values calculated from 1h data (HK test) and from 10 days data (including the 1 hour TEST) . For each HK time, the SCI data were extracted and correlated with the simultaneous IDs. This allowed to calculate correlations over about 15.000 points instead of the 3600 points of the 1h HK test. . The improvement is evident.

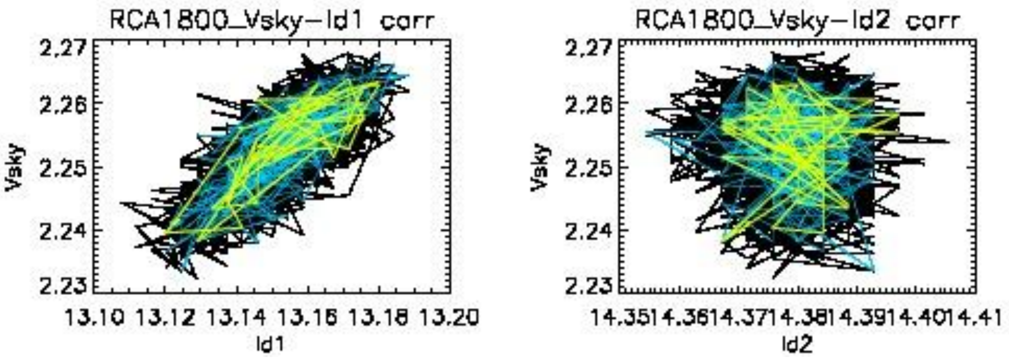

Figure 9 Correlation between Total Power data and Id currents sampled at 1Hz (black), at 0.125 Hz (cyan) , at 0.0156 Hz (yellow): see the good correlation with Drain current powering radiometer M1 and not with that of radiometer M2: it will impact also on the effect shown in the next pictures.

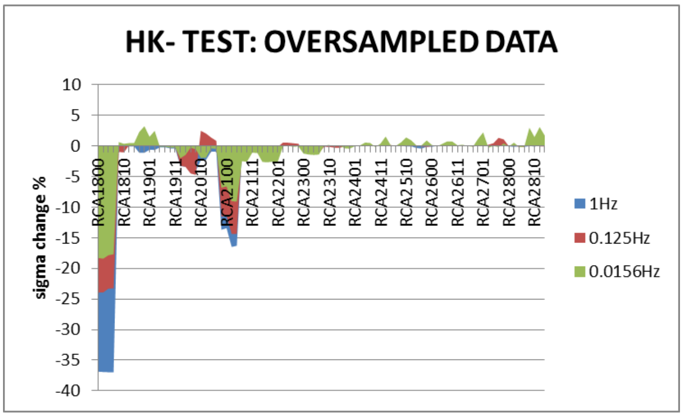

Figure 10 sigma improvement after data cleaning (based on correlations with Id1 currents) and oversampling to the nominal SCI data frequency : sigma are compared in percent w.r.t. un-cleaned data

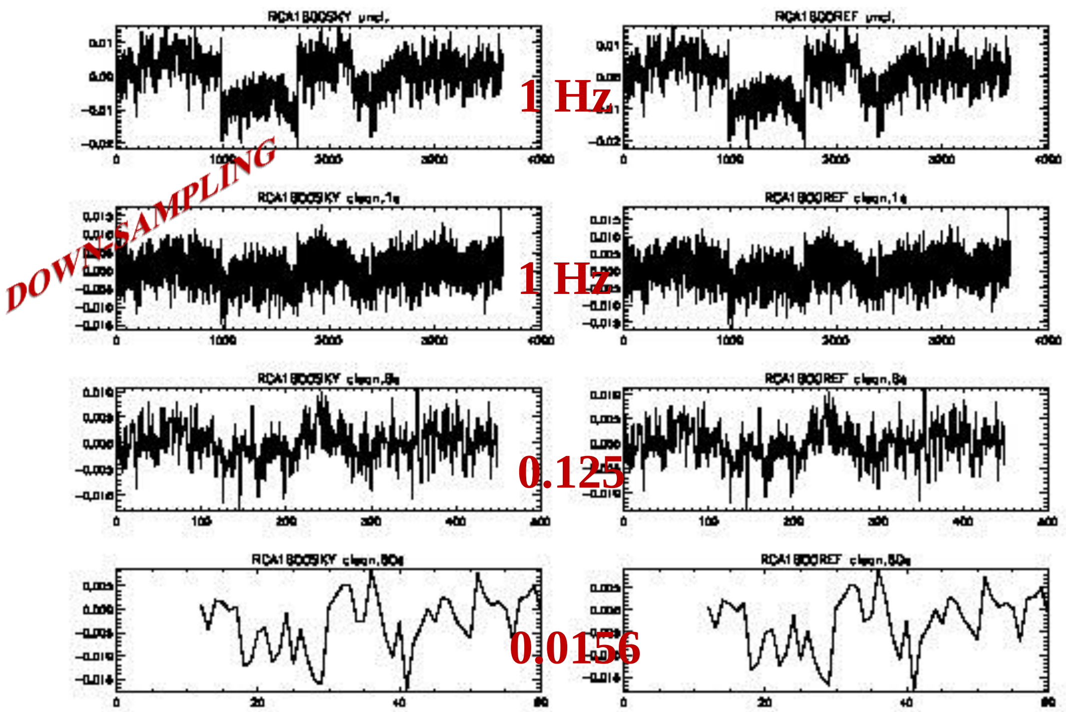

Figure 11 LFI1800: Comparison between total power data (sky on the left, ref on the right) for (top to bottom) : 1) un-cleaned SCI data down-sampled to 1Hz (Raw), data down-sampled and cleaned at: 2) 1Hz , 3) 0.125 Hz, 4) 0.0156 Hz

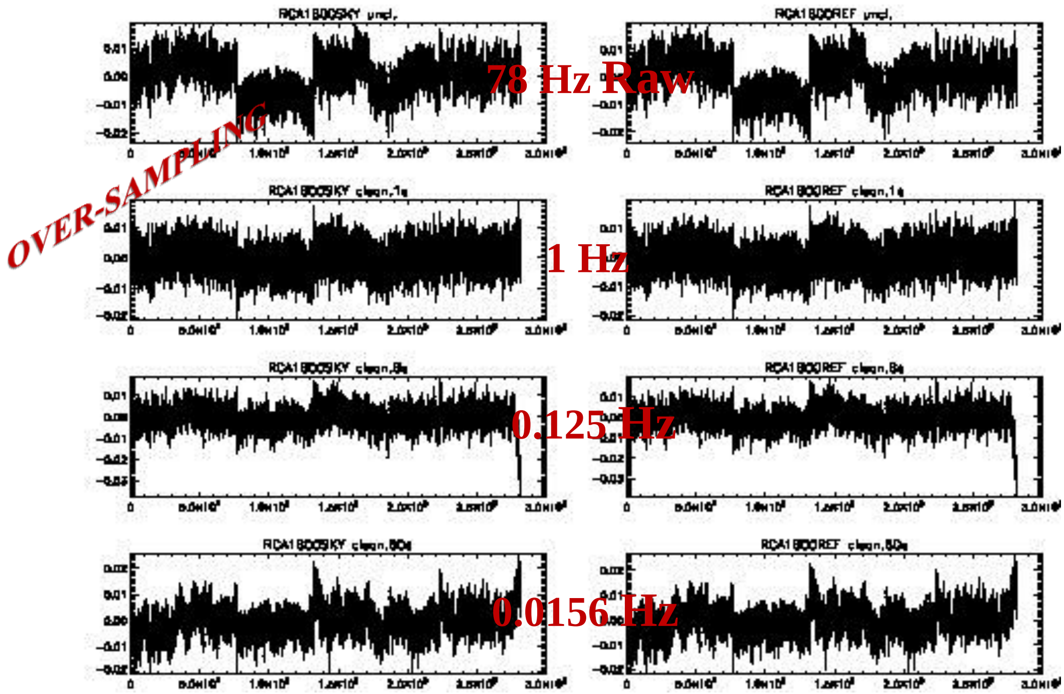

Figure 12 LFI-1800: Comparison between total power data (sky on the left, ref on the right) for (top to bottom) : 1) un-cleaned data sampled at 78 Hz (nominal frequency for 70 GHz channels). SCI data corrected basing on the model of Id HK resampled to 78 Hz respectively from : 2) 1Hz ; 3) 0.125; 4) 0.0156 Hz. The accuracy in removal increases with the HK sampling frequency.

4.4 IDENTIFICATION OF ANOMALIES

Many channels show large instabilities in the drain currents. It is evident that the origin of some SCI data instabilities can be easier recognized as due to electric instabilities when the HK sampling is faster. Although this does not implies the possibility to always remove or mitigate the effect, it is nevertheless important and useful to have all the elements to correctly address the problem, either in the purpose of correction and data flagging. The example of LFI1800 is shown in Figure 13.

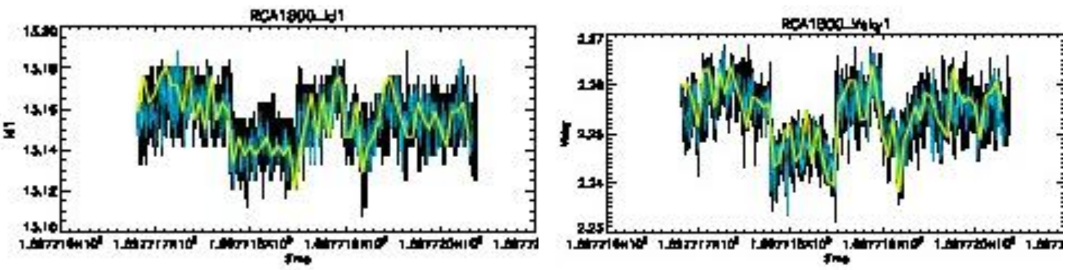

Figure 13 Left panel: LFI 18M1 Drain current during the 1h HK test . Id data are sampled at 1Hz (black) and down-sampled to 0.125 Hz (cyan) and to 0.0156 Hz (yellow). The same color convention is used in the right panel to display the behavior of SCI-data in channel LFI1800 (Sky is down-sampled from its nominal 78 Hz frequency to the HK frequency).Plots show that: i) most of the Sky signal instabilities are very similar to HK features; ii) The HK down-sampling limits the possibility to relate 1:1 features observed in SCI data with the HK behavior.

5. CONCLUSIONS

Results from the 1h HK Test performed during OD 888 (HK sampling frequency increased from 0.0156 Hz to 1 Hz) and from a 20 days data set containing the HK Test) demonstrate that the accurate monitoring of Drain currents is very powerful in: i) tracking and address anomalies caused by electric instabilities ii) mitigating effects caused by electric instabilities in the Front End LNAs power suppliers or in the harness.

The analysis showed that :

- several channels (especially 70 GHz channels) show good correlation (from 0.3 to 0.85) between total power SCI signals and a weighted combination of the drain currents powering the two corresponding coupled LNAs. Correlation is not as large for the differenced signals as for the total power signals .
- In some cases, the model developed, correlating drain currents and SCI data, is able to provide very good results (standard deviation improvements up to 50%, depending on channels) when applied to correct Total power data; smaller but not negligible improvements are observed when applied differenced data. Corrections applied directly (coefficients measured from diff data fitting) or indirectly (total power correction applied before calculating diff data) to diff data show some benefit, varying with channels. However, it seems that the 'direct correction' has larger power in predicting improvements respect to the corresponding indirect approach.
- Corrections applied at Total power level are expected to be very useful in the purpose of a possible LFI Gain Calibration using the reference load signal, by calculating the term DV/V. Several channels show very good improvement (by several percent) in the DV/V stability after data correction (in two cases improvements larger than 23 % (LFI21) and 100 % (LFI18) are observed). Improvements (from few percent up to 12 % as in the case of LFI 18) are measured also in the Gain Modulation Factor (the accuracy of this result strongly depends also on the Sky model, here not considered: hence it is thought that it can be improved) .
- Results from the HK Test were analyzed as a function of the HK sampling frequency (1Hz, 0.125 Hz, 0.0156 Hz). It was confirmed that: i) the correlation coefficient is larger when the sampling is faster. ii) the model capabilities to correct SCI data from electric instabilities are proportional to the HK sampling frequency, providing more accurate fit coefficients and smaller quantization effects when the HK is re-binned to match the SCI data sampling frequency.
- Anomalies in SCI data induced by electric instabilities can be easier recognized when the HK sampling frequency is faster. Actually, the default sampling rate (0.0156 Hz) avoids or strongly limits this possibility in the most cases.

All the above results and conclusions support the LFI Instrument request to increasing the sampling frequency at least to 0.125 Hz; higher (preferred) sampling frequencies would be appreciated, depending on the technical capabilities.