HIFI ILT Stability

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30Nov2007	Release		**114**		**Summary added.**

Table of Contents

1 General

All derived plots and reports can be found on the WIKI page (Test overview/Stability link):
http://www.sron.rug.nl/hifi_icc/protected/ILT/index.html

Documents can be found for local use at: http://www.sron.rug.nl/hifi_system_aiv/plans-procedures.html

Information on HCSS documents (QLA, IA, etc) can be found:
- via the HIFI ICC web page http://www.sron.rug.nl/hifi_icc under ICC pages
- via the Herschel Science Centre Development Team page http://www.rssd.esa.int/SD-general/Projects/Herschel/hscdt
  under the link HIFI Release Documentation
- directly to ftp://ftp.rssd.esa.int/pub/HERSCHEL/csdt/releases/hifi_doc/index.html

The status of the (CUS) scripts of the various test modes can be found on
http://www.sron.rug.nl/hifi_icc/protected/cus/

A description can be found in “Detailed description of CUS scripts for HIFI FM tests” under the link CUS_DOC (http://www.sron.rug.nl/hifi_icc/protected/cus/CUS_DOC/).

1.1 Applicable Documents

SRON-U/HIFI/ PL/2000-010	HIFI D&V plan	Issue 1
SRON-G/HIFI/PL/1999-001	AIV plan for HIFI	Issue 1.0
SCI-PT-IIDA-04624	Instrument Interface Document Part A (IIDA)	Issue 3.1
SCI-PT-IIDB/HIFI-02125	HIFI Instrument Interface Document Part B (IIDB)	Issue 3.2
SRON-G/HIFI/SP/1998-001	HIFI Instrument Specification	Issue 4.4
SCI-PT-ICD-07527	Packet Structure Interface Control Document (PSICD)	Issue 5.0

2 Introduction

Fig. 1 below outlines the four phases of the FM ILT stability measuring campaign. Half way thru the ILT stability tests it became evident that there was a serious instability problem in SIS band 1, 2, 3, 4, and HEB bands 6, 7 [1, 2]. Fundamentally, the problem was found to be related to the local oscillator (LO) power amplifiers and multiplier drive level [3-5]. As a side note; the band 5 LO, operating in the range 1100-1200 GHz utilizes a beamsplitter to inject the local oscillator signal. The LO is driven hard by default and thereby "stable" (AM noise minimized). Aside from the 'optical attenuator' issue we have mapped regions of instability, obtained the relevant time constants needed to properly run the instrument, measured system and differential stability times, and in general terms: learned how to operate this wonderfully complex instrument. This information is now embedded in HSPOT (V. Ossenkopf *et al.*) and been used in the thermal vacuum (TV) and performance verification (PV) stability tests plans. Much of the presented analyses are based on preparatory work by V. Ossenkopf [9-14].

The addition of optical attenuators [6, 7] has been found to resolve most of the instability problem for SIS bands 1, 2, 3, 4 and HEB band 6. However, due to the large dynamic range (up to 10 dB) of some of the LO output signals (notably B3a, B6, B7) it is not possible to optimize the amount of attenuation needed without loss in frequency coverage. Thus a compromise between frequency coverage and optical attenuation had to be made. The bands most adversely affected by this compromise are B3a and B7, as evidenced by the measured data.

IF Stability
- IF Amplifier Warm-up
- Total Power Stability WBS, HRS
- Spectroscopic Stability WBS, HRS

System Stability
- LO Warm-up
- Total Power Stability
- Spectroscopic Stability

Differential Stability
- LO Warm-up
- Load-Chop
- Internal Load
- Beam Switching
- Frequency switching

Parametric Stability
- B6, B7 Stability as a function of Vbias
- B6, B7 Stability as a function of LO Pump current
- B5 Stability as a function of B-field.

Fig 1. *Overview of the stability test during the FM ILT. Parametric stability tests in band 1-4 were taken before the addition of optical attenuation, and henceforth deemed uncharacteristic*. These are not included in this report.

During ILT, several time constants important to HIFI operation were studied

- **IF-1 amplifier turn-on stabilization (Section 4.4)**
- **LO warm-up, System and Differential (Section 5.5)**

We have found that the IF-1 amplifier warm-up time is approximately 10 minutes. The LO warm-up time is found to vary from 30 minutes to 55 minutes (5*t) and not surprisingly, the longest time constants are associated with the more hardware complex B6, B7 LO chains.

Differential (DBS/Load-chop) warm-up time ranges from 3 minutes after LO turn-on for B1 to about 15 minutes for B7 (5t). Note that it is **absolutely critical** that in B6 and B7 the LO's be retuned every few minutes initially, gradually decreasing until t=2-3t, according to the system stability in Table 3, Section 5.5. On the time scales 60-300s, differential measurement may be possible in the SIS bands (no LO returning needed); however one has to consider the possible negative effect on calibration accuracy and baseline ripple.

"In-band" frequency change settling time has been observed in nearly all bands, however it is most evident in band 6 and 7 (some examples are provided). The latter is likely due to the Hot Electron Bolometer (HEB) sensitivity to LO power variations and general complexity (many cascaded stages) of the B6, B7 LO chains. No clear pattern has been observed, and as a rule there should be a LO-tuning command in bands 6 and 7 five minutes after a frequency change event. One should also be aware that large frequency changes will presumably effect the LO thermalization time. To circumvent this problem it may be wise to keep the power delivered to the LO constant.

Excess LO noise, as judged from the calculated equivalent "noise fluctuation bandwidth" appears in general correlated with receiver instability. We map out the following regions of having excessive LO noise/instability. Some of this is likely due to terrestrial H2O and should go away in TV/PV.

B1a: 517-526 GHz, mild

B2a: 650 GHz in TP

B2b: 750-760 GHz (H2O?)

B3a: 848 GHz

B4a: 1000.6, 1018 GHz Severe excess LO noise.

B4b: 1092 GHz

B6a: 1480-1500 GHz.

B6b: 1470 GHz

B7a: 1710-1720 and 1762 GHz

B7b: Everywhere except band edges.

Some general Stability observations:

- For beam splitter bands (B1, B2, B5) WBS sub-band 1-3 have similar stability, with sub-band4 being generally a bit worse (7-8 GHz channel). Thus observations should preferentially take place in WBS sub-bands 1-3.
- Diplexer SIS bands (B3, B4), are most stable in the center of the IF (WBS sub-band 2, 3), followed by WBS sub-band 1 (4-5 GHz) and WBS sub-band 4 (6-7 GHz).

- HEB bands are most stable in WBS sub-band1 (3.8-4.8 GHz) where Tsys is the highest!! In the IF frequency range 2.4-2.8 GHz (WBS sub-band 3) Tsys is lowest (-3dB mixer gain corner frequency) but the stability is also the worst. (Most sensitive to standing wave power fluctuations …).
- At frequencies where there is significant instability, the use of only the center WBS / HRS channel is still workable (galactic observations).
- Increasing the HEB mixer bias to 1mV improves the stability, but degrades Tsys by ~ 16%. Changing the mixer bias from 0.4mV to 0.6 mV has no effect. (0.5mV is nominal). This' maybe a useful tradeoff when observational baselines are poor (Section 7).
- Increasing the HEB LO pump drive level from nominal (40-50uA) to 30 uA improves the system stability but also degrades Tsys (~ 30%.). (Section 7).
- For the HEB mixers, the LO power cutoff is ~ 58 uA. Less then this results in unusable behavior. In addition at very low LO pump levels the mixer IF output impedance gets large and complex. This is likely to results in poor baseline subtraction.
- In case of the B5 mixer: When the B-field is properly set, a +- 6% deviation from nominal has a negligible effect on system stability. Conversely, increasing the B5 mixer bias by 0.1mV from nominal has no effect, decreasing the bias by 0.1mV degrades the system stability. (Section 7).

IF2 feedback was extensively investigated in March 2007 and compared to before the repair [9]. The results are presented in Section 4.7.

Frequency switch differential measurements were limited to 20 minutes and one frequency per LO band due to a lack of time. Results are promising for the SIS bands, and questionable for the HEB mixer bands. Further investigation is needed in TV and PV. Table in section 6.4.4.

The mean and standard deviation of the system and differential Allan times per LO sub-band are complied in the sections 5.8 and 5.9 tables. As evidenced by the standard deviation, there is a large spread in the Allan stability time per LO sub-band. This spread is real, and caution must be taken in interpreting these tables. System stability graphs are provided in this report for each LO-sub-band with the measured results incorporated into HSPOT.

The B6, B7 HEB system stability results are very poor (notably band 7b). Some of this is likely due to modulation of the LO-mixer standing wave, due to microphonics, between the LOU and FPU cryostats [3-5].

In Jan 2007, ILT1 temperature investigations [8] confirmed the need for very stringent temperature control. As a result the external IF cables running between the FPU cryostat and spectrometer rack were thermally insulated in Feb.2007, aluminized insulation installed on the windows of room 50, and the air-conditioning turned off >= 12hours prior to stability measurements. In principal, temperature information (housekeeping) during all ILT observations is recorded in the database. The indicated thermal upgrades to room 50 were found to be adequate to render thermal drift noise a second, or even third, order effect during ILT.

In May 2007, several ground loops were removed from the ILT test setup, just prior to the (final) ILT-3 phase.

Platforming effects (UC-1.1.5) and baseline offsets in the spectrometers for various power levels have not been derived in detail. This in light or more severe instabilities from other sources. The data is however available in the database if explicitly needed.

The influence of Bragg cell heating on baseline stability of the WBS (UC-1.1.3.1) is
Currently under investigation by the KOSMA team.

3 Vector Scans (David Teyssier)

Due to limited available ILT stability test time it was chosen to select test frequencies at 1) a stable Vd2 bias, and 2) an unstable Vd2 bias. Vd2 refers to the drain voltage on the last power amplifier (PA). It is the PA that controls the drive power to the multiplier chain. As it became apparent that the HIFI system stability could not be adequately described by two frequencies per LO band, this plan was abandoned for measuring the HIFI system stability at the primary science LO frequencies. Upper and lower sidebands were chosen so as to optimize homogenous frequency coverage. Nevertheless differential and parametric stability continued to follow the 'stable' and 'unstable' frequency plan, essentially due to a lack of time to take more data points.

The vector scans presented in Fig. 2, and derivative of the vector scans in Fig. 3 are useful to for understanding the fundamental issue that faced HIFI. Not obvious from the vector scans is the excess amplitude LO noise that manifests itself when the power amplifiers are not driven into saturation. Section 7, parametric study, has up-to-date vector scans of B6, B7 with optical attenuation.

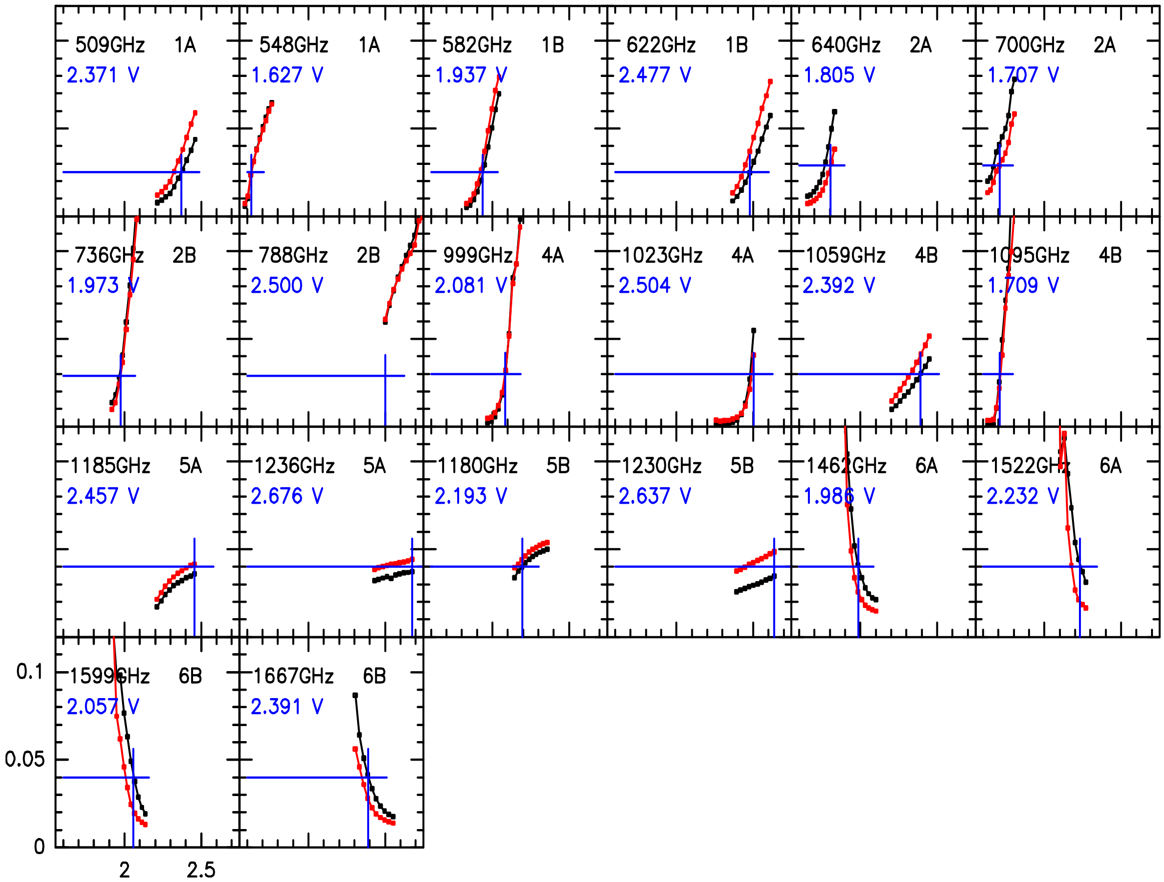


Fig. 2 Vector scans of mixer current as a function of Drain2 Voltage (Vd2) <u>before</u> inclusion of optical attenuation. Traces with a large slope present a problem. B5 with a beam splitter as LO-diplexer is driven very hard, and the dImix/dVd2 slope is small at optimum LO bias. Refer also to section 7, parametric

stability measurements for updated vectors scans.

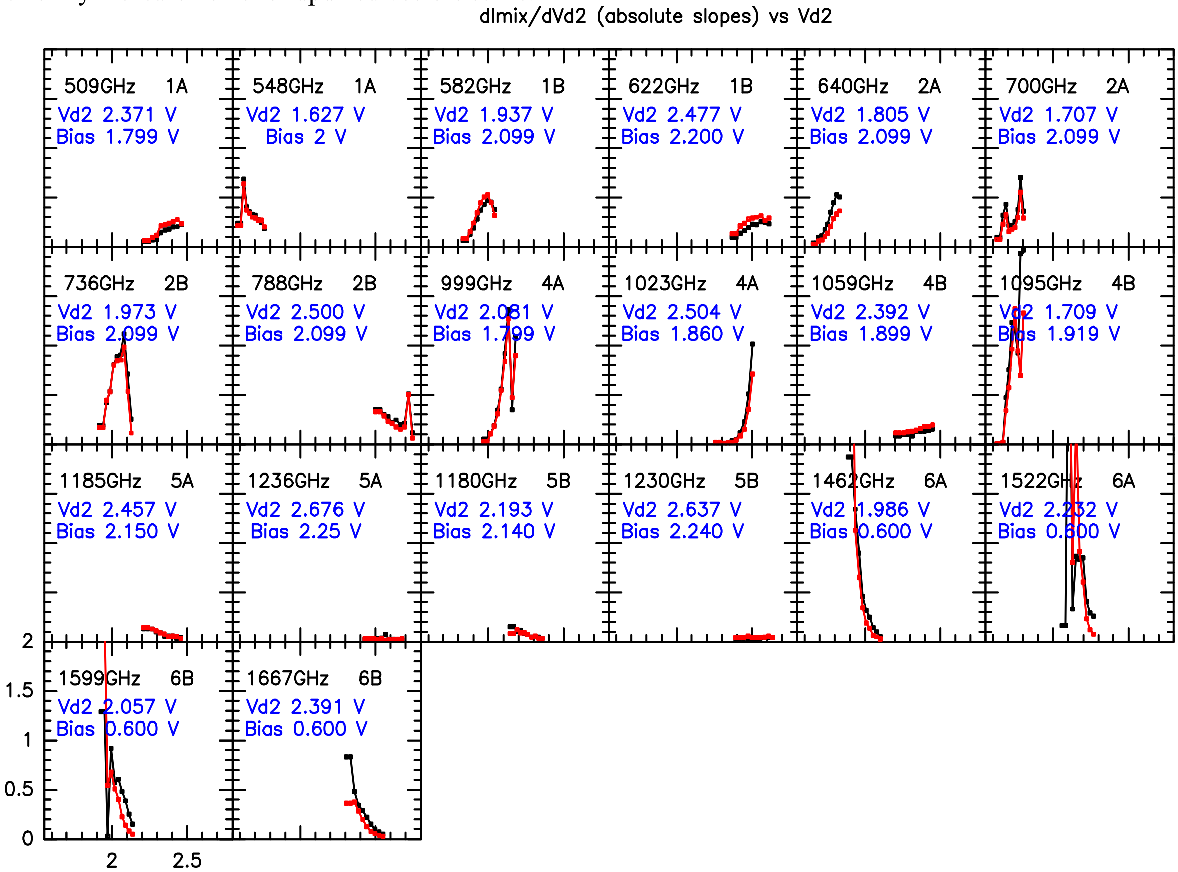


Fig. 3. Derivatives of Fig. 2. Note the ‘zero’ slope in Band 5, indicative that the LO is being driven correctly.

3.1 Updated Vector scans B5, B6, B7

The Band 5 LO has no need for optical attenuation, being driven hard (beamsplitter band) and having little variation across the LO passband. This is not so for B6 and B7, where the use of optical attenuation is limited by the available LO power and dynamic range.

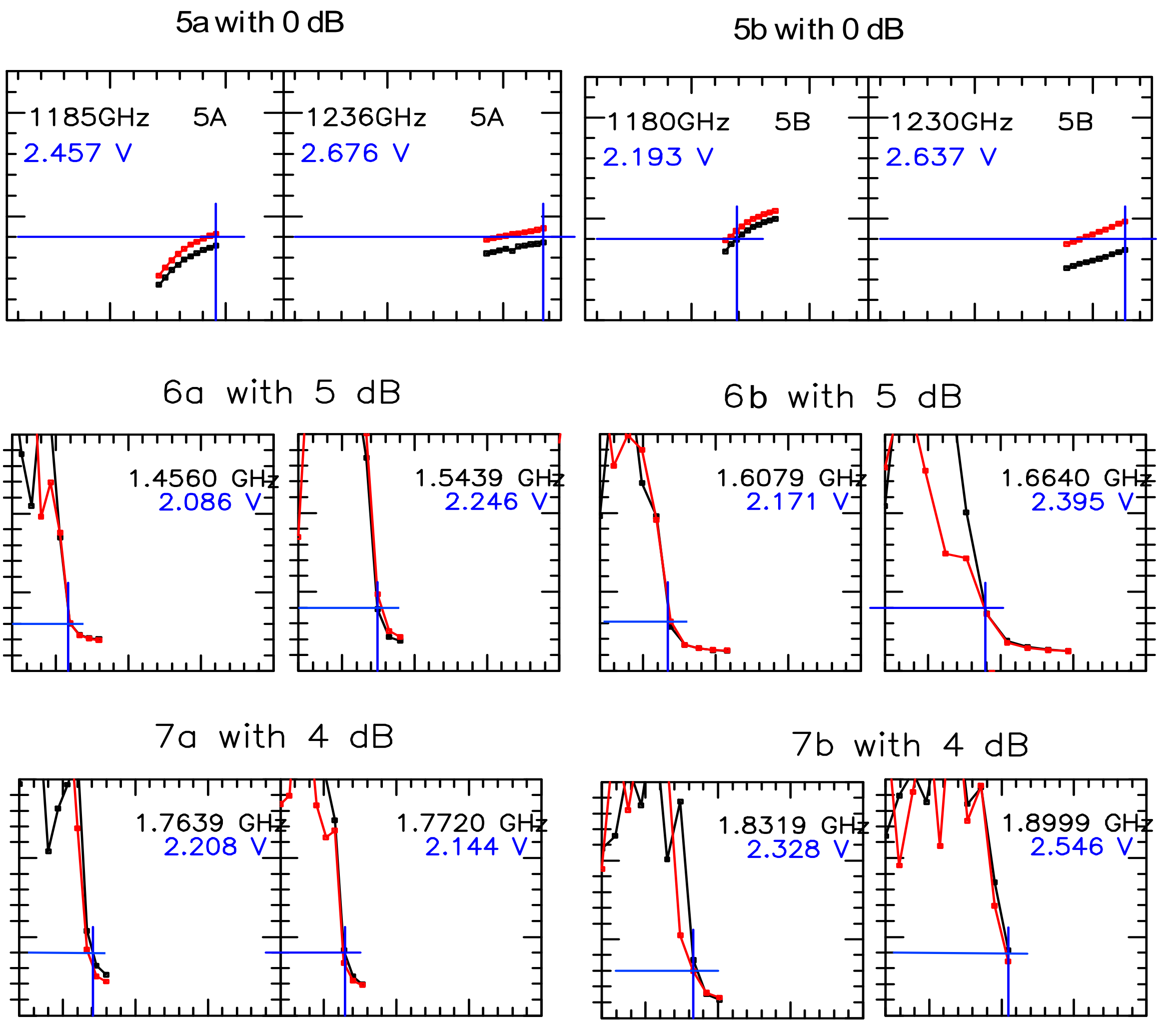


Fig. 4. Band 5 has no optical attenuation (same as Fig 3, used for comparison). Clearly, even with the 4-5 dB attenuation B6, B7 remain very sensitive to bias noise.

4 IF Stability (LO-OFF)

4.1 Objectives (B1-B7)

Verify amplitude stability of the IF system including that of the spectrometers by biasing the junction at 8mV with LOU turned off.
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref]. [ref].
Search for, and measure platforming effects (UC-1.1.5) spectrometers
The influence of Bragg cell heating on baseline stability of the WBS (UC-1.1.3.1) ???
Characterize IF system stability with IF1 switched OFF (IF2 On), and IF1 warming up.
Characterize the effect of IF2 feedback with chopper position.

Note: HEB mixers (B6, B7) produce no shot noise. Biasing the HEB mixer at 8mV results in the electrons having an effective temperature of approximately 10K. Thus we still measure the IF stability albeit under illuminated in the case of the wideband spectrometers.

4.2 Test Procedure (B1-B7)

Configure instrument, stabilize if necessary. Mixer is unpumped (LO-off)

```
for mixer_band = 1, 7 do begin {
    select WBS and HRS in low resolution mode
    IF 1 Off, IF2 On
    adjust IF level
    perform WBS cal using the internal calibration source (zero-comb, RD20)
     for i = 0, 450 do {                (30 minutes with IF 1 off, IF 2 on)
      acquire WBS/HRS spectrum {4sec}
     }

      IF 1 On, IF2 On, Junction biased at 8 mV (SIS and HEB)
      adjust IF level
      perform WBS cal using the internal calibration source (zero-comb, RD20)
        for i = 0, 450 do {             (30 minutes warm up with IF 1 on, IF 2 on)
          acquire WBS/HRS spectrum {4sec}
        }

      perform WBS cal using the internal calibration source (zero-comb, RD20)
        for i = 0, 900 do {             (IF stability measurement, repeat 1 hour)
          acquire WBS/HRS spectrum {4sec}
        }

      perform WBS cal using the internal calibration source (zero-comb, RD20)
      for Vbias = 5, 10 step 1 {        (5, 6, 7, 8, 9, 10mV, IF 1 On, IF2 On)
        acquire WBS/HRS spectrum {30sec}
      }

      perform WBS cal using the internal calibration source (zero-comb, RD20)
         for Vbias = 5, 10 step 5 {     (5, & 10mV, IF 1 On, IF2 On, 1h total)
           for i = 0, 225 do {          (15 minutes CBB, 15 minutes HBB)
              select chopper internal Cold BB
              acquire WBS/HRS spectrum {4sec}
              select chopper internal Hot BB
              acquire WBS/HRS spectrum {4sec}
              }
         }
}
```

end

CUS script names:

- *Testmode_stability_noIF1*
- *Testmode_stability_IF_system* (1h warm up measurement)
- *Testmode_Parameter_Scan_Investigation (5,6,7,8,9,10mV measurement)*
- *Testmode_stability_internal_load (1h internal load measurement)*

Note1: This test will take 3h per band
Note2: Dead time between spectrometer is assumed negligible.

4.3 Output

The IF total power spectroscopic Allan variance as a function of integration time (device biased in the normal state (8mV).
IF2 feedback.
Knowledge of platforming spectrometers
.
Analyses summary
-Time for which the total noise exceeds the radiometric noise by 100%.
-Noise fluctuation bandwidth for each radiometer sub-band.
-Slope of the drift term β (HSPOT, not shown here)

-Figure of merit for IF2 feedback.
-Compare with the theoretical variances.
(see for reference IS-04.02.03.05-01 and IS-04.02.03.05-02).

4.4 IF-1 Turn-on Stabilization Time Tabulated (all bands)

IF-1 Warmup Time (5τ)

Band	H-pol (min)	V-pol (min)	Obsid
1	6.5	3.5	268463924
2	10.5	5	268463931
3	12	10	268463859
4	15	10	268463875
5	6.5	6.5	268463883
6	>= 12	12	268463939
7	10	8	268463867

SIS bands
HEB bands.

Table 1 IF-1 Warm-up time in minutes. 5 τ is derived from the exponential total power (system) response.

4.5 IF Total Power and Spectroscopic Stability per WBS sub-band

4.5.1 Band 1 IF stability (no LO)

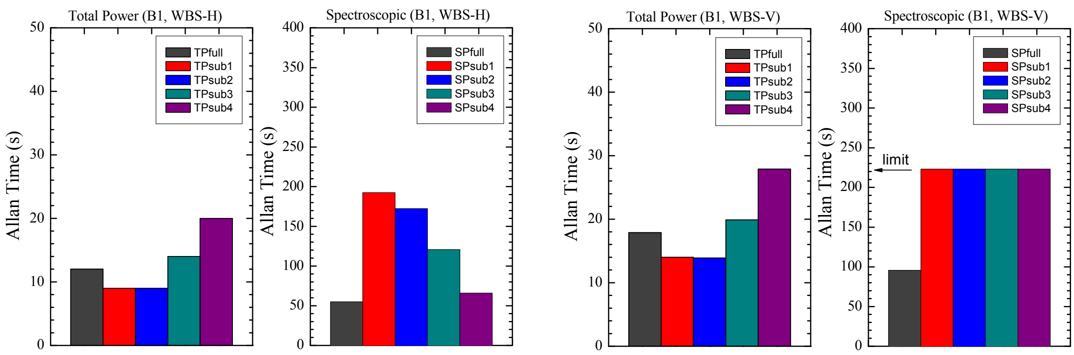


Fig. 5. Band 1 WBS total power and spectroscopic IF stability for H and V. The measurement limit is 225s.

4.5.2 Band 2 IF stability (no LO)

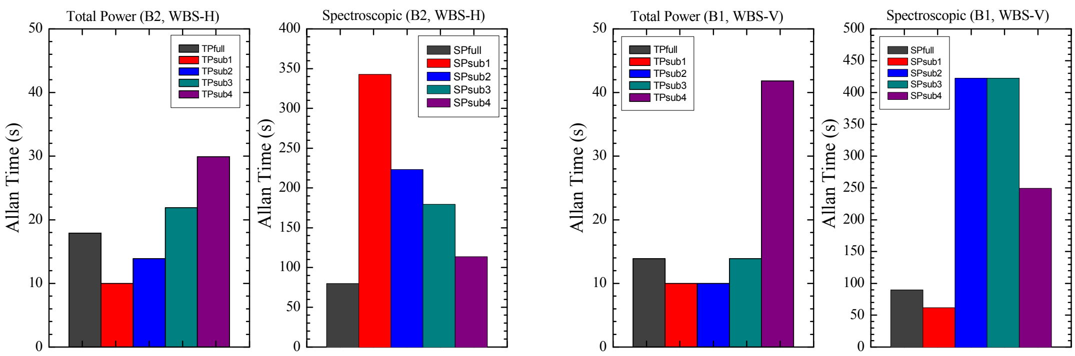


Fig. 6. Band 2 WBS total power and spectroscopic IF stability for H and V. The measurement limit is 450s.

4.5.3 Band 3 IF stability (no LO)

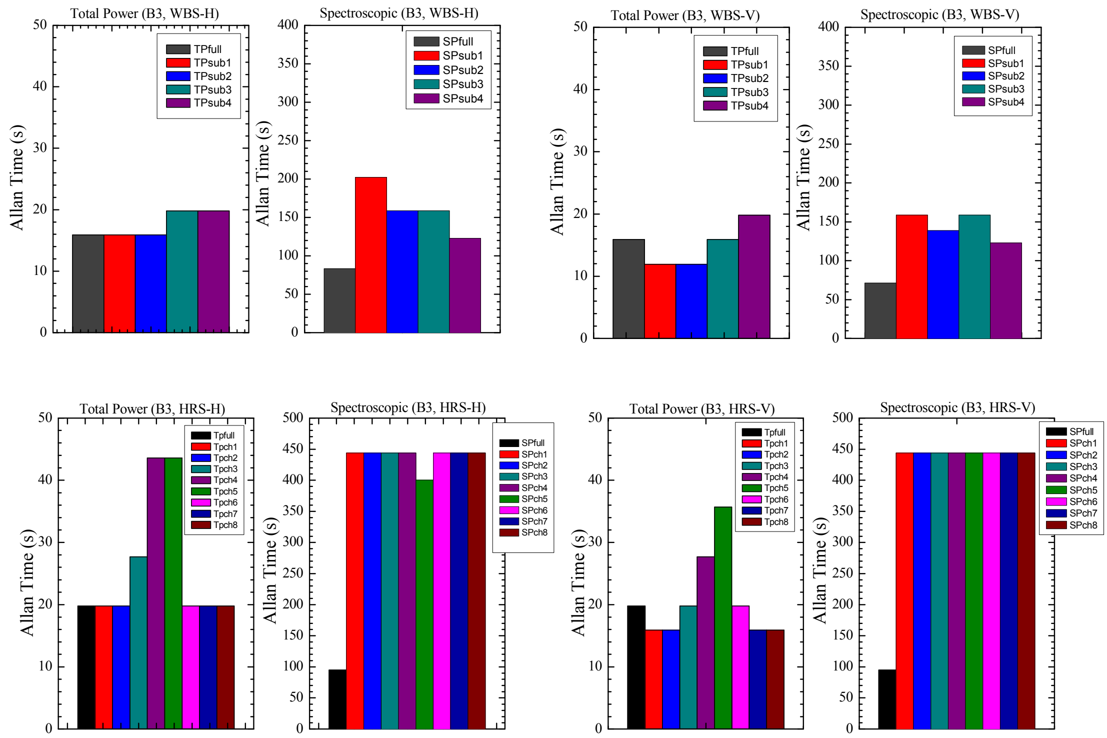


Fig. 7. Top: Band 4 WBS total power and spectroscopic IF stability for H and V. Bottom: HRS total power and spectroscopic IF stability. The measurement limit is 450s. In the center of the IF band HRS TP stability is generally best.

4.5.4 Band 4 IF stability (no LO)

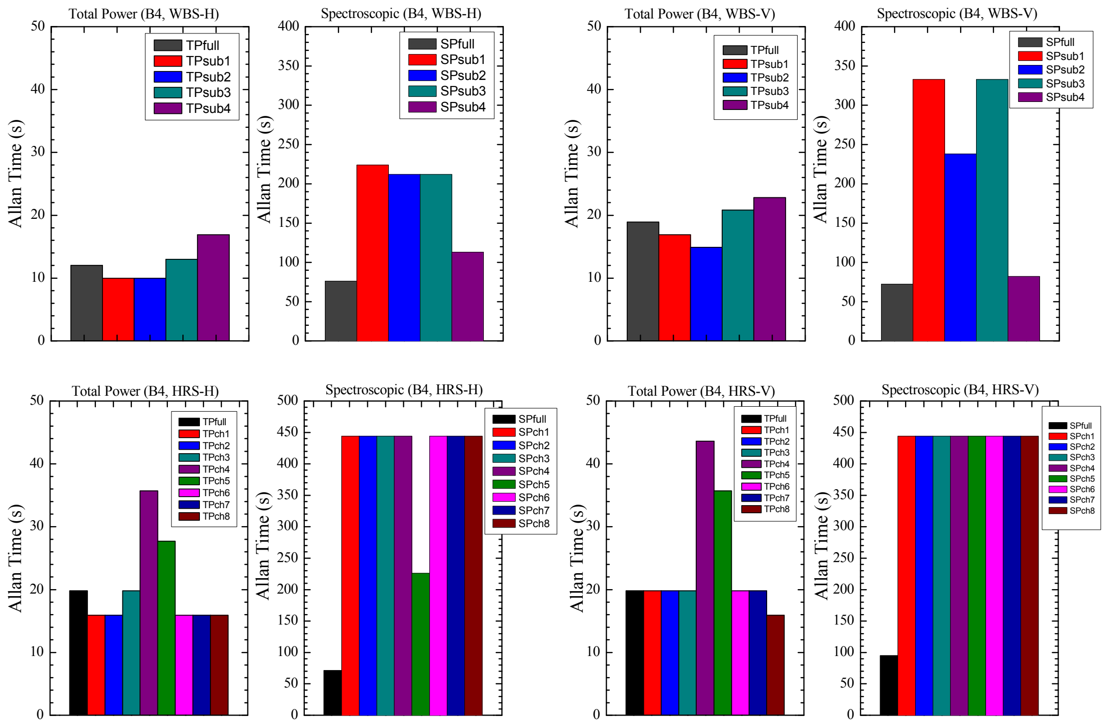


Fig. 8. Top: Band 4 WBS total power and spectroscopic IF stability for H and V. Bottom: HRS total power and spectroscopic IF stability. The measurement limit is 450s. In the center of the IF band HRS TP stability is generally best.

4.5.5 Band 5 IF stability (no LO)

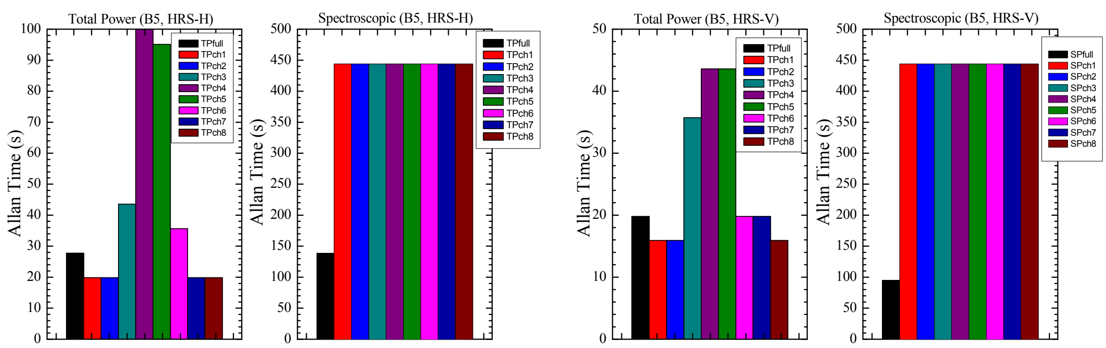


Fig. 9. Band 5 HRS total power and spectroscopic IF stability for H and V. The measurement limit is 450s. IF and system stability for B5 are generally better then in other bands. In the center of the IF band HRS TP stability is generally best.

4.5.6 Band 6 IF stability (no LO)

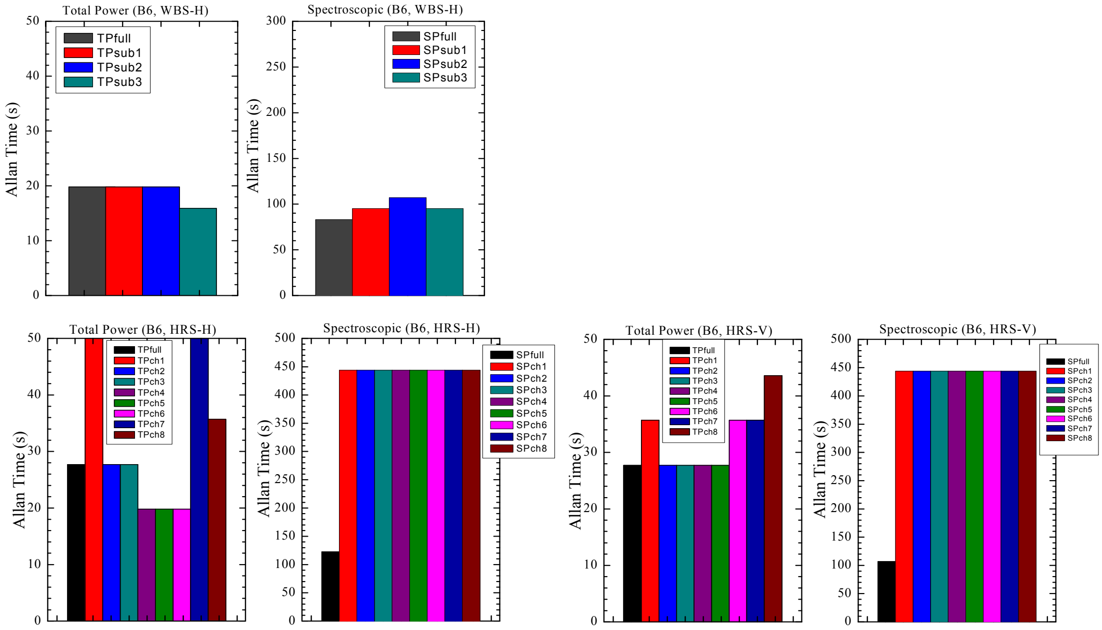


Fig. 10. Top: B6 (HEB) WBS total power and spectroscopic IF stability for H and V. Bottom: HRS total power and spectroscopic IF stability for H and V. The measurement limit is 450s.

4.5.7 Band 7 IF stability (no LO)

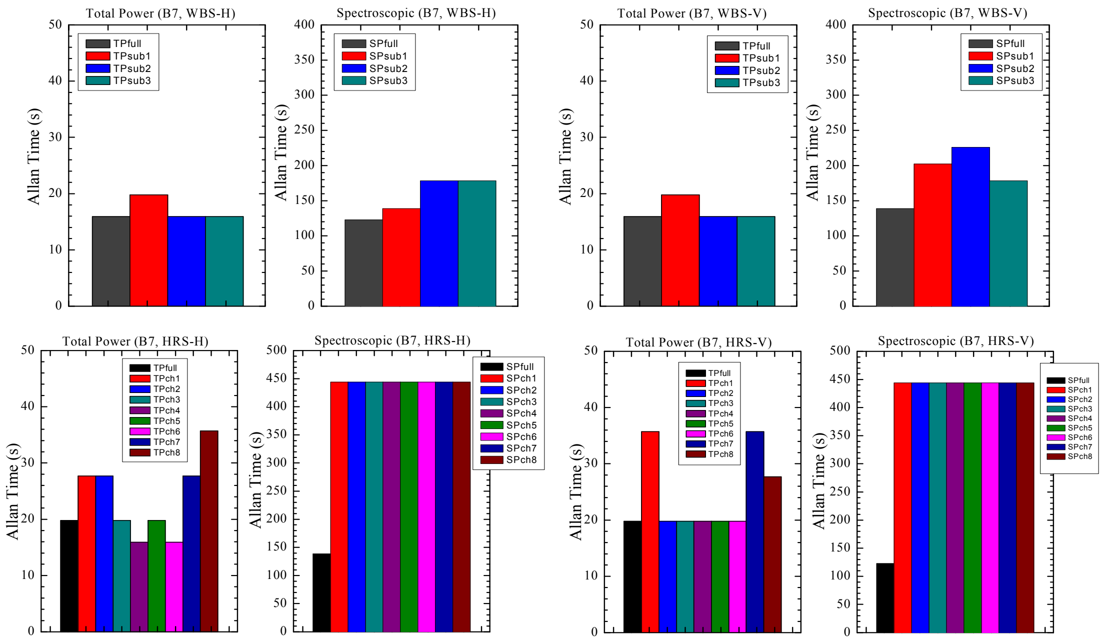


Fig. 11 Top: B7 (HEB) WBS total power and spectroscopic IF stability for H and V. Bottom: HRS total power and spectroscopic IF stability for H and V. The measurement limit is 450s.

4.6 IF stability Tabulated (all bands)

WBS-V

	Continuum (spec >15s)					Spectroscopic (spec >100s)				
Band	Full	Sub1	Sub2	Sub3	Sub4	Full	Sub1	Sub2	Sub3	Sub4
1	21.9	17.9	13.9	21.9	29.9	89.7	223.2	223.2	223.2	223.2
2	13.9	10	10	13.9	41.8	89.7	61.8	422.4	422.4	249.1
3	15.9	11.9	11.9	15.9	19.8	71.3	158.5	138.7	158.5	122.9
4	16.9	16.9	14.9	20.8	22.8	72.3	332.9	237.8	332.9	82.3
5*	20.0	12.0	16.0	20.0	35.9	123.8	447.1	554.9	554.9	447.1
6*	20.0	20.0	20.0	16.0		203.6	227.6	227.6	255.5	
7	15.9	19.8	15.9	15.9		138.7	202.1	225.9	178.3	

WBS-H

	Continuum (spec >15s)					Spectroscopic (spec >100s)				
Band	Full	Sub1	Sub2	Sub3	Sub4	Full	Sub1	Sub2	Sub3	Sub4
1	13.9	10	10	17.9	21.9	61.8	223.2	143.5	113.6	69.7
2	17.9	10	13.9	21.9	29.9	79.7	342.7	223.2	179.3	113.6
3	15.9	15.9	15.9	19.8	19.8	83.2	202.1	158.5	158.5	122.9
4	11.9	9.9	9.9	12.9	16.9	76.3	223.9	212	212	113
5*	16.0	12.0	12.0	16.0	20.0	83.8	359.3	255.5	323.4	107.8
6	19.8	19.8	19.8	15.9		83.2	95.1	107	95.1	
7	15.9	19.8	15.9	15.9		122.9	138.7	178.3	178.3	

* From IF-2 test on 07 March 2007. The ILT-2 spectroscopic system stability appears to have been more stable then during ILT3.To some extend this is because data was taken for 60 min rather than 30 min (ILT3). system Total Power results are very similar.

Table 2. IF stability times (s) for all bands. Orange is marginal. Yellow: no data (2.4-4.8 GHz IF for HEB bands 6 and 7). Data was taken with the mixers biased at 8 mV. In the case of the HEB mixers, this equates to a thermal input noise of ~ 10K, the critical temperature of the NbN base material.

4.7 IF-2 Feedback

We compare 15 minute chopped measurements on Int. Cold, with the junction biased above the gap as a noise source, (5, 10 mV bias), no LO. Ideally the difference spectra subtract. For the B6, B7 HEB mixers no shot noise is generated, and we compare ~ 10K thermal noise amplified by IF1. In this case the IF2 amplifier feedback is found negligible, a possible indication that the feedback mechanism may lie in the mixer bias path.

B1 seems to have gained the most by the IF repair (~11 dB), apparently because the feedback problems were most severe in this band. The remainder of the bands has gained approximately 5-6 dB from the IF2 repair.

Important: No *degradation in the system stability is observed due to the IF2 feedback (Fig.'s 8-14). In other words, IF2 feedback is stable and should be able to calibrate out.*

4.7.1 Band 1 IF2 Feedback

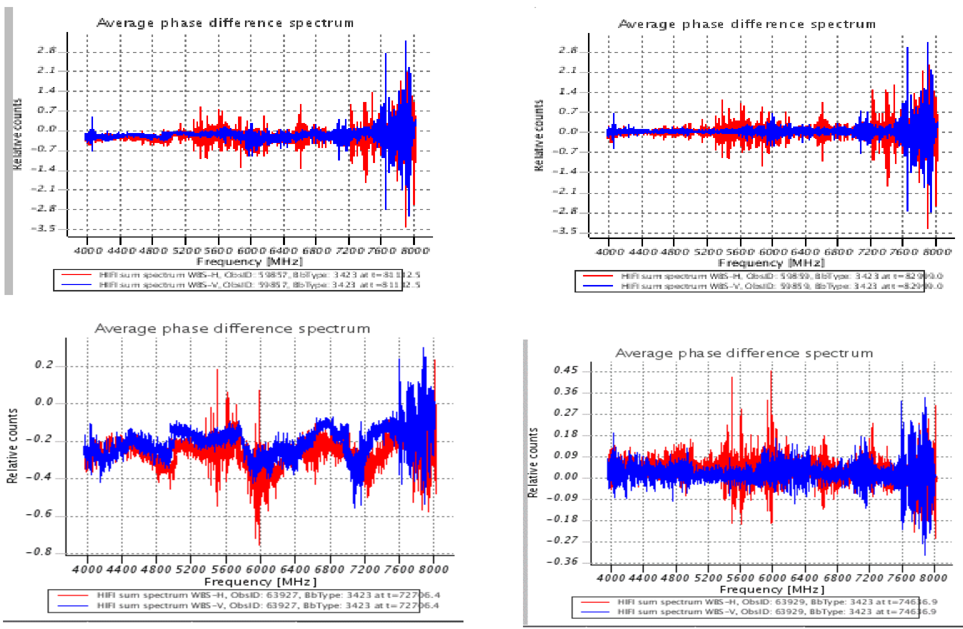


Fig. 12. Band 1. *Top: Before repair, 5 & 10 mV Bottom: After repair, 5 & 10 mV. In the high end of the band the improvement is ~ 11 dB.*

4.7.2 Band 2 IF2 Feedback

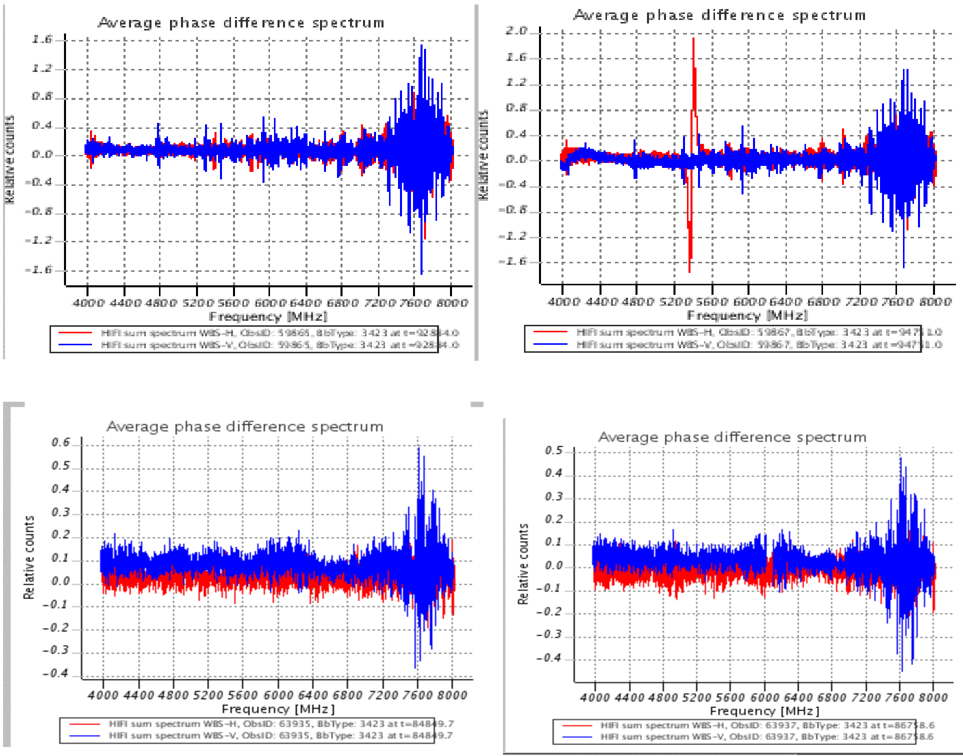


Fig. 13. Band 2. Top: Before repair, 5 & 10 mV Bottom: After repair, 5 & 10 mV. In the high end of the band the improvement is ~ 6 dB.

4.7.3 Band 3 IF2 Feedback

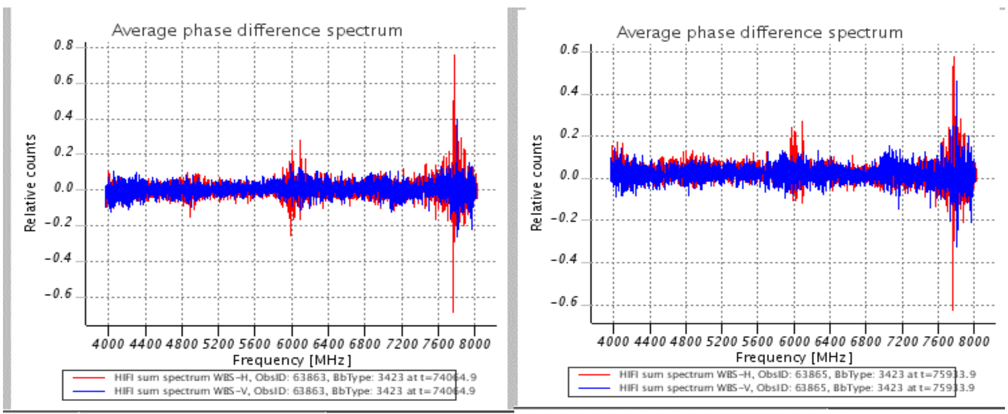


Fig. 14. Band 3. No data before repair. *After repair, 5 & 10 mV shown.*

4.7.4 Band 4 IF2 Feedback

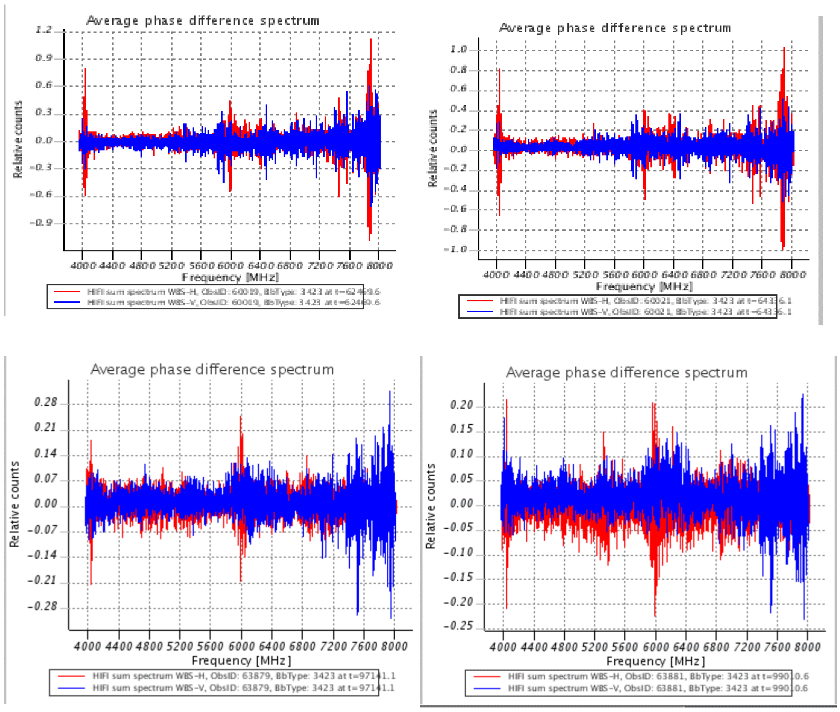


Fig. 15. Band 4. Top: Before repair, 5 & 10 mV Bottom: After repair, 5 & 10 mV. In the high end of the band the improvement is ~ 6 dB.

4.7.5 Band 5 IF2 Feedback

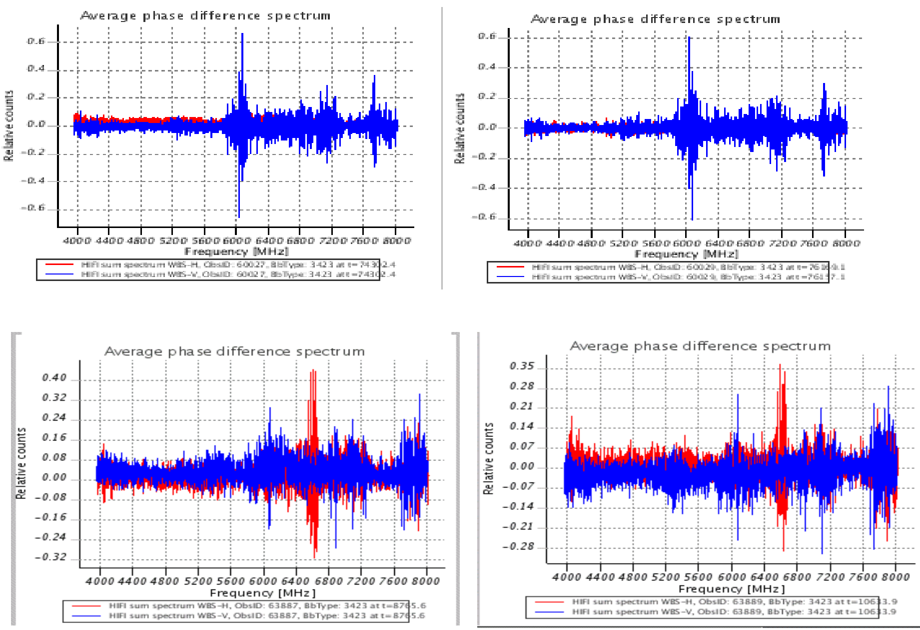


Fig. 16. Band 5. Top: *Before repair, 5 & 10 mV Bottom: After repair, 5 & 10 mV. In the high end of the band the improvement is ~ 5 dB.*

4.7.6 Band 6. IF2 Feedback

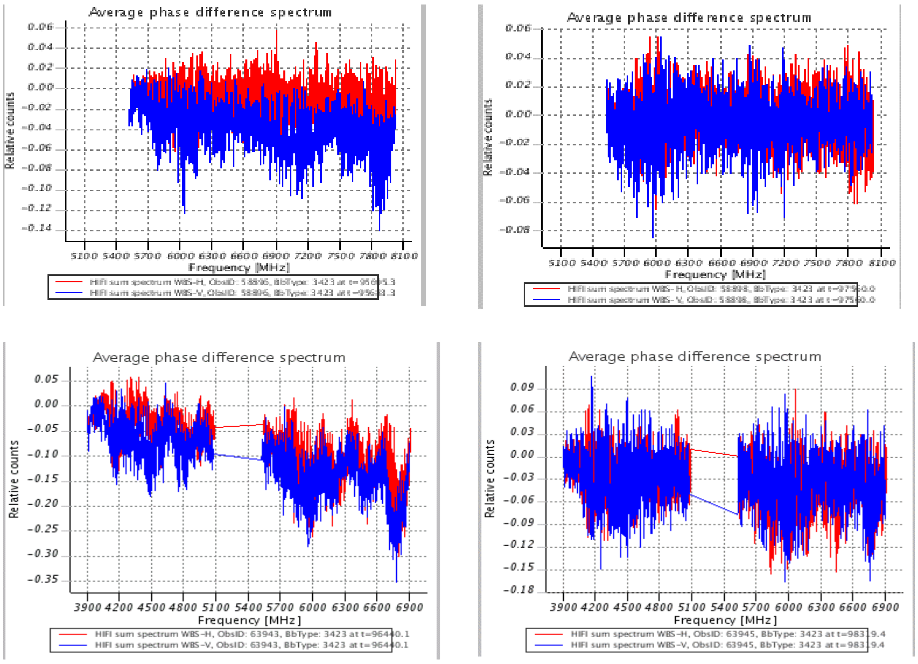


Fig. 17. Band 6. Top: Before repair, 5 & 10 mV Bottom: After repair, 5 & 10 mV. In the case of the HEB mixer it produces ~ 10K thermal noise. IF1-IF2 feedback appears not effected.

4.7.7 Band 7 IF2 Feedback

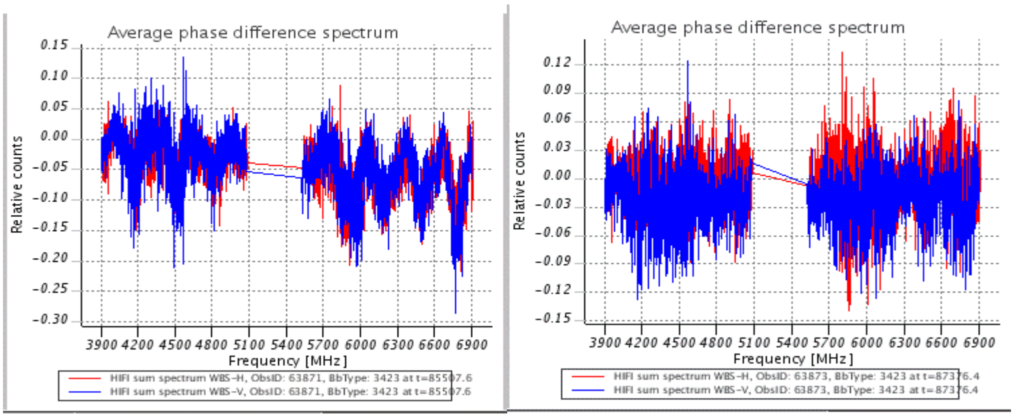


Fig. 18. Band 7. Top: After repair, 5 & 10 mV. No data before repair.

4.7.8 Example Band 4 IF2 Feedback.

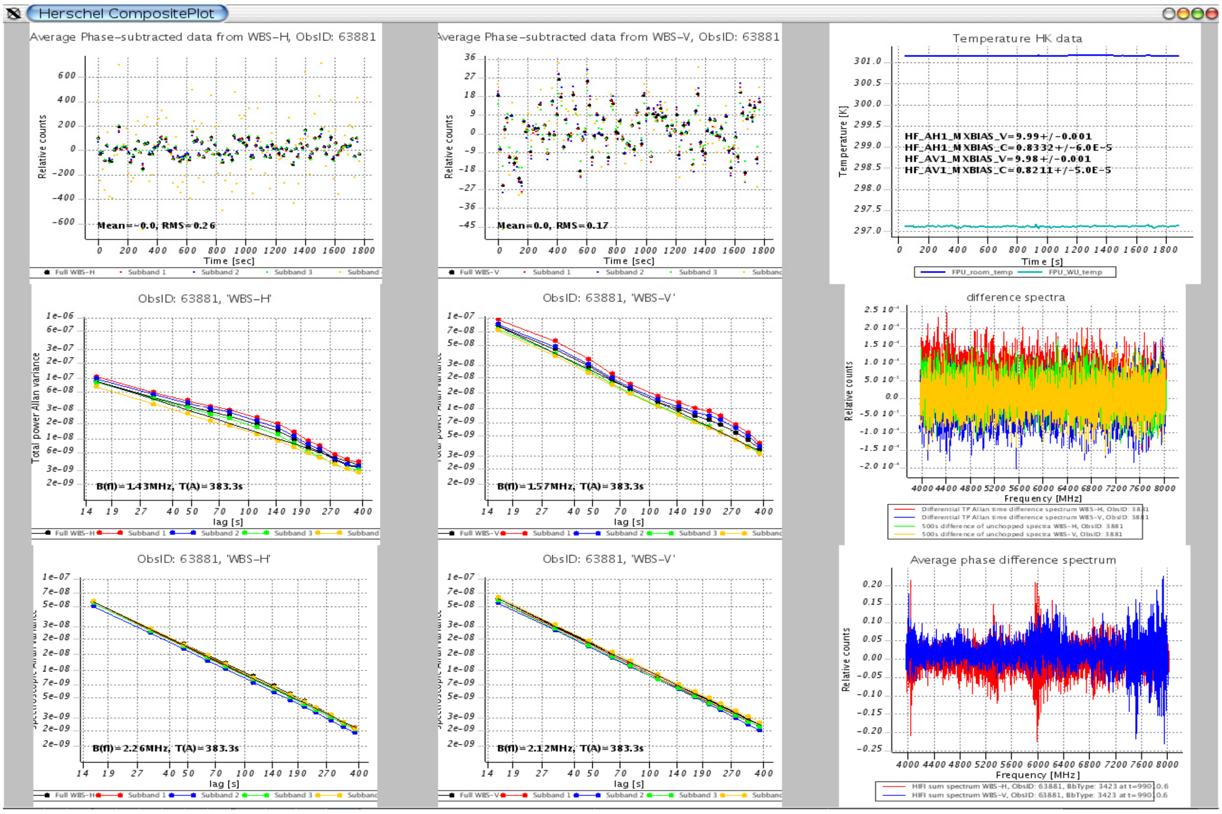


Fig. 19. Example of IF2 feedback/*Stability in B4, 10 mV repaired*. Spectroscopic stability and baselines are very good, an indication that the IF 2 feedback is stable and subtracts out. For an explanation of the plot see section 4.7.9 below.

4.7.9 Composite Stability Plot explained.

In Fig 16 above the following information is displayed:

Top row Left: Time series WBS-H
Top row Center: Time series WBS-V
Top row Right: House keeping data (Temperature or Bias current).
Middle row Left: Total Power Stability H (5 curves, black is Full or 8000 channels).
Middle row center: Total Power Stability V 5 curves, black is Full or 8000 channels).
Middle row right: Difference spectra H and V (red, blue) overlaid with difference spectra after 200s. (green, yellow). This shows platforming/baseline corruption.
Bottom row left: Spectroscopic Stability H
Bottom row center: Spectroscopic Stability V
Bottom row right: Average same-phase difference spectrum. (IF2 feedback in this case).

5 System Stability

5.1 Objectives

Verify the total power amplitude stability of HIFI instrument for each band, due to broadband gain variations, component noise, LO standing wave...
Determine LO stabilization time.
Determine LO settling time.
Search for plat forming effects, baseline offsets.

5.2 Test Procedure (B1-B5)

```
Turn On LO                              (some frequency near the center of the band)
Configure instrument, nominal bias, B-field, diplexer etc
for mixer_band = 1, 5 do begin  {
    select WBS and HRS in low resolution mode  (4 second readout))
    select Internal Cold BB
    adjust IF level
    Turn LO/PA's OFF                    (Wait a 3 minutes)
    Turn LO/PA's back On                (Same LO frequency)
    perform WBS cal using the internal calibration source (zero-comb, RD20)
              acquire WBS/HRS spectrum {4sec}
      }

      for freq = flo1, flo2     {              (2 LO frequencies near the edge of the band)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
           for i = 0, 600 do {           (40 min)
              acquire WBS/HRS spectrum {4sec}
           }
              select focal plane chopper, fast chop mode.
              perform WBS cal using the internal calibration source (zero-comb, RD20)
                 for i = 0, 20 do {                    (Measure Y-factor, 20 seconds)
                    select chopper internal Cold BB
                    acquire WBS/HRS spectrum {1sec}
                    select chopper internal Hot BB
                    acquire WBS/HRS spectrum {1sec}
                 }
      }
}
end
```

<u>CUS script name:</u>

- *Testmode_stability_intcold (1h LO stabilization)*
- *Testmode_stability_intcold (40min Int. Cold load measurement)*
- *<u>Testmode_stability_internal_load (Obtain Y-factor)</u>*

5.3 Test procedure (B6-B7) WBS

Note1: Total integration time 60 + (2*40) = 140 minutes.
Housekeeping data should be acquired and stored throughout this and other test procedures.

```
Turn On LO                              (some frequency near the center of the band)
Configure instrument, nominal bias, diplexer etc
for mixer_band = 6, 7 do begin  {
```

```
    select both ¾ WBS (2.4 GHz)  in low resolution mode  (1 second spectrometer readout))
    select Internal Cold BB
    adjust IF level
    Turn LO/PA's OFF                  (Wait a 3 minutes)
    Turn LO/PA's back On              (Same LO frequency)
    perform WBS cal using the internal calibration source (zero-comb, RD20)
      for i = 0, 3600 do {                (60 min LO stabilization)
              acquire WBS spectrum {1sec}
      }

     for freq = flo1, flo2     {          (2 LO frequencies near the edge of the band)
       adjust IF level
       perform WBS cal using the internal calibration source (zero-comb, RD20)
          for i = 0, 1200 do {       (20 min)
             acquire ¾ WBS (2.4 GHz)  spectrum {1sec}
          }
              select focal plane chopper, fast chop mode.
              perform WBS cal using the internal calibration source (zero-comb, RD20)
                for i = 0, 30 do {                    (Measure Y-factor, 30 seconds)
                   select chopper internal Cold BB
                   acquire WBS/HRS spectrum {1sec}
                   select chopper internal Hot BB
                   acquire WBS/HRS spectrum {1sec}
                }
     }
}
end
```

<u>**CUS script name:**</u>

- *Testmode_stability_intcold (1hour LO stabilization)*
- *Testmode_stability_intcold (2 * 20 min Int. Cold load measurement)*
- <u>*Testmode_stability_internal_load (Obtain Y-factor)*</u>

Note1: Total integration time 60 + (2*20) = 100 minutes.
Note2: Readout ¾ WBS (2.4 GHz) to achieve 1 second readout time.
Housekeeping data should be acquired and stored throughout this and other test procedures.

5.4 Output

-Total power Allan variance for each (H+V) WBS & HRS channel and subband.
-Spectroscopic Allan variance for each (H+V) WBS & HRS channel and subband (zero-order baseline subtraction).
-ASCII data files to be used in HSPOT/generate tables-plots etc.
-Binning Allan Variance
-Tsys vs. IF frequency
-LO settling time.

-Time for which the total noise exceeds the radiometric noise by 100%.
-Noise fluctuation bandwidth for each radiometer sub-band.
-Slope of the drift term β
-Compare with the theoretical variances.
(see for reference IS-04.02.03.05-01 and IS-04.02.03.05-02).

CompositeStabilityPlot() output
<u>Display plots in a 3x3 matrix for each obsid (WBS and HRS in **two separate** pages)</u>

1) Time series of the average spectrometer level (WBS-H: 5 curves, or HRS-H: 9 curves)
2) Time series of the average spectrometer level (WBS-V: 5 curves, or HRS-V: 9 curves)
3) House Keeping bias vs. time.
4) Spectrometer sub-bands vs. IF frequency (H + V). WBS: 8 curves, HRS: 2 curves
5) Total power Allan variance for each sub-band and full spectrometer (WBS-H: 5 curves, HRS-H: 9 curves)
6) Total power Allan variance for each sub-band and full spectrometer (WBS-V: 5 curves, HRS-V: 9 curves)
7) Spectroscopic Allan variance for each sub-band and full spectrometer (WBS-H: 5 curves, HRS-H: 9 curves)
8) Spectroscopic Allan variance for each sub-band and full spectrometer (WBS-V: 5 curves, HRS-V: 9 curves)
9) Difference spectrum (H + V) for both WBS and HRS Spectrometers (4 curves). This shows platforming.

5.5 LO Warm-up Tabulated (all bands)

LO Warm-up Time (5τ)

Band	Total Power (min)	Frequency (GHz)	Obsid	Differential (min)	Frequency (GHz)	Obsid
1a	30	509	268476280	5	494	268510476
1b	30	582	268461236	3.5	563	268510729
2a	40	640	268459469	10	640	268511312
2b	40	736	268461220	13	728	268511362
3a	40	812	268471048	20	814	268511420
3b	40	878	268471066	13.5	869	268511669
4a	30	995	268483530	15	982	268509805
4b	40	1095	268460379	20	1108	268510072
5a	30	1185	268459366	10	1127	268510773
5b	40	1180	268460362	10	1191	268510564
6a	50	1462	268467526	15	1444	268511851
6b	47	1599	268471030	15	1581.4	268512252
7a	50	1723	268471084	7 ?	1716.6	268513243
7b	55	1897	268471102	x	x	x

SIS bands

HEB bands. Frequent LO tuning needed during first 2-3τ (Total Power time period).

Table 3. Total Power and Spectroscopic LO warm up stabilization time (5τ). 5τ is derived from the exponential total power system and differential response. For HEB bands 6. 7 it is important that there is a frequency 'LO-retune' after turning on the LO, out to about 2-3 Total Power time constants. Note that during the ILT campaign no heaters were used to thermally stabilize the LO. In the event LO heaters can be used effectively in space, then the time constants are expected to reduce, albeit not go to zero (MMIC and multiplier Schottky diodes still need to equilibrate).

5.6 LO Warm-up Examples

5.6.1 B1b LO warm-up (Differential measurement)

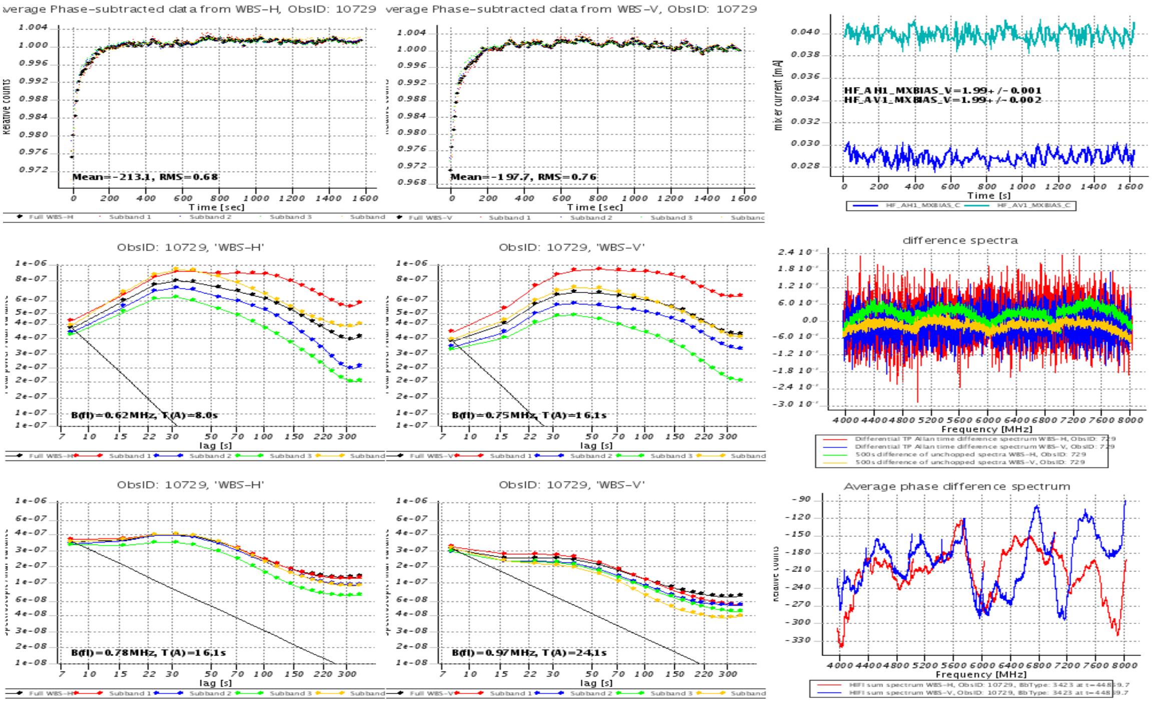


Fig. 20. 563 GHz internal Load differential measurement

5.6.2 B1b LO warm-up (System measurement)

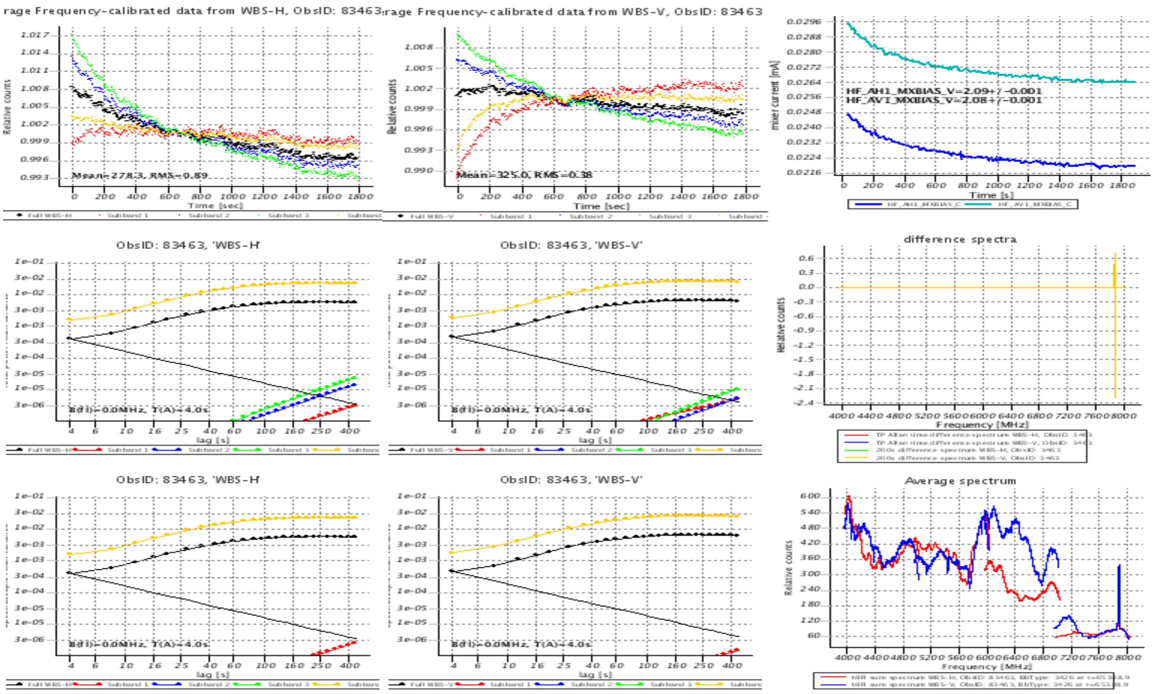


Fig. 21. 582 GHz internal CBB system stability. Note spur at 7.8 GHz.

5.6.3 B2b LO warm-up (Differential measurement)

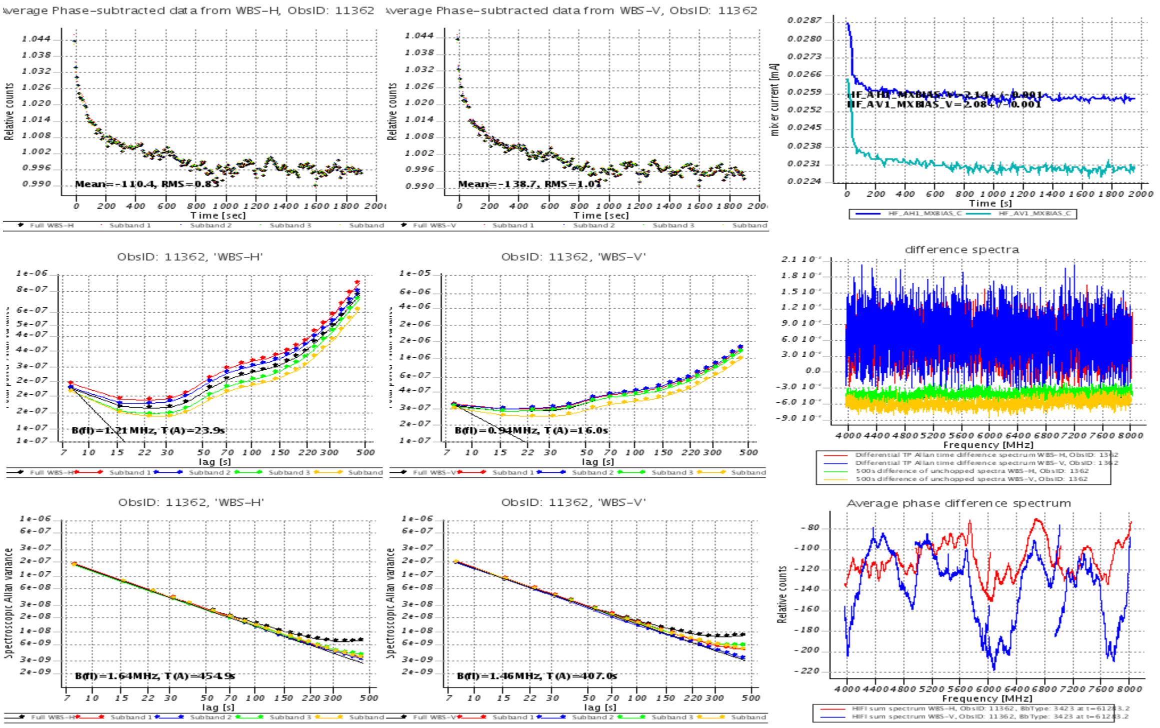


Fig. 22. 728 GHz internal Load differential measurement.

5.6.4 B2b LO warm-up (System measurement)

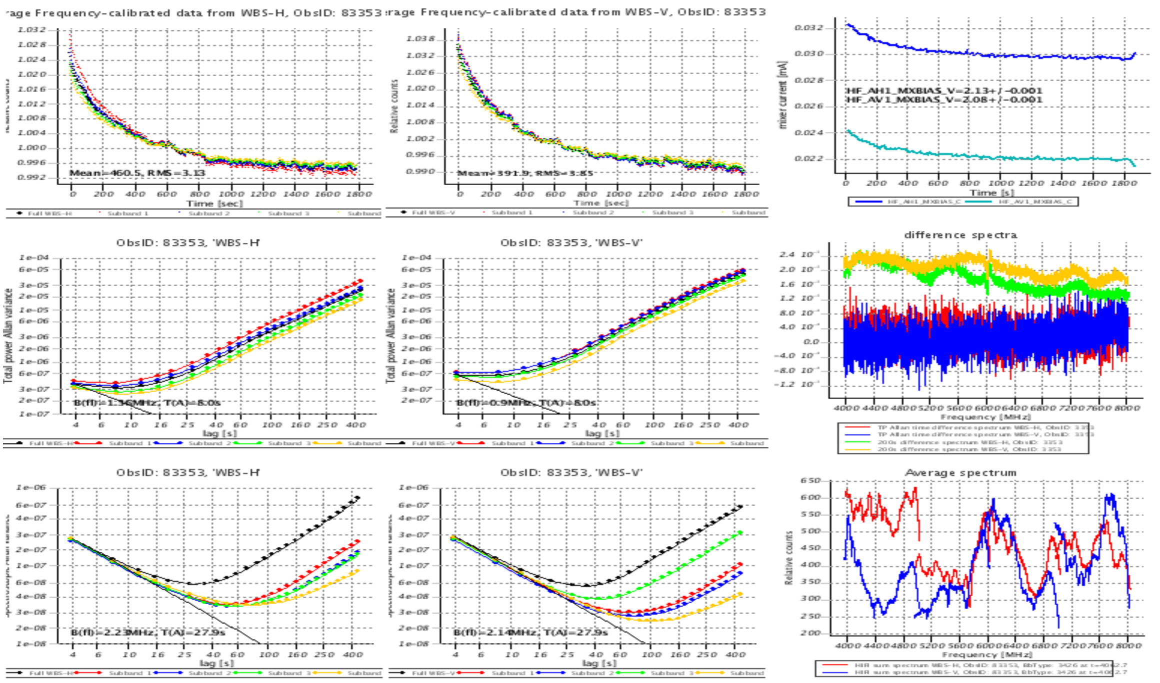


Fig. 23. 736 GHz internal CBB system stability.

5.6.5 B3a LO warm-up (Differential measurement)

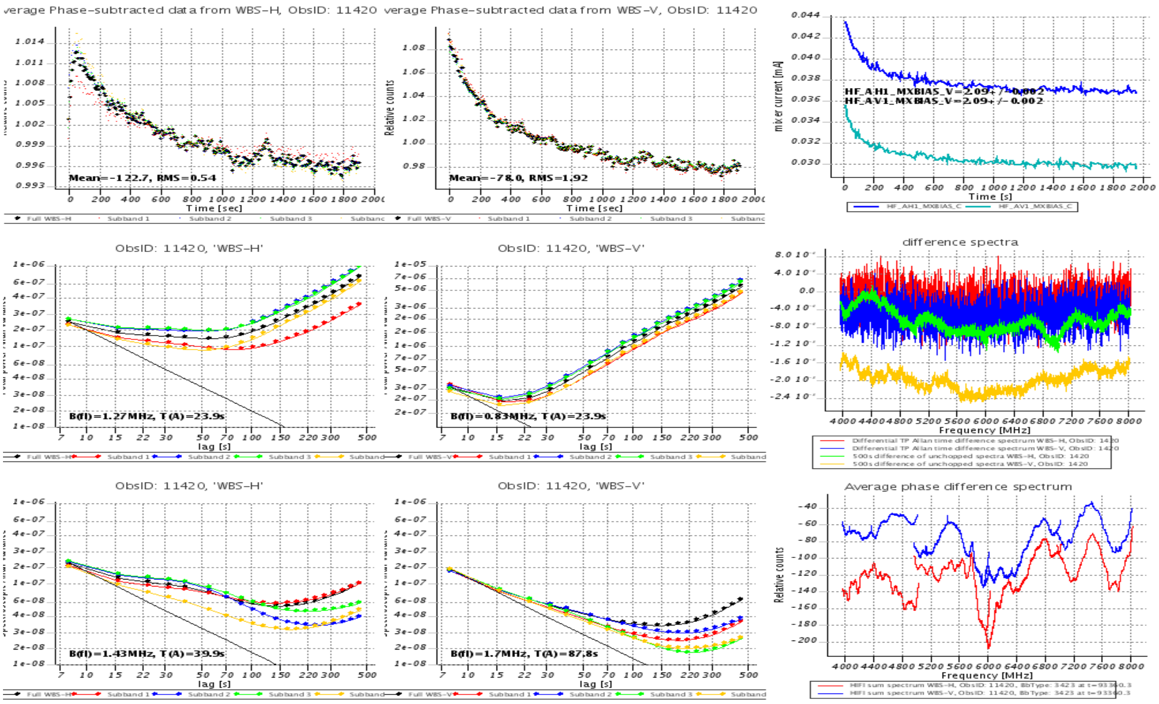


Fig. 24. 814 GHz internal Load differential measurement.

5.6.6 B3a LO warm-up (System measurement

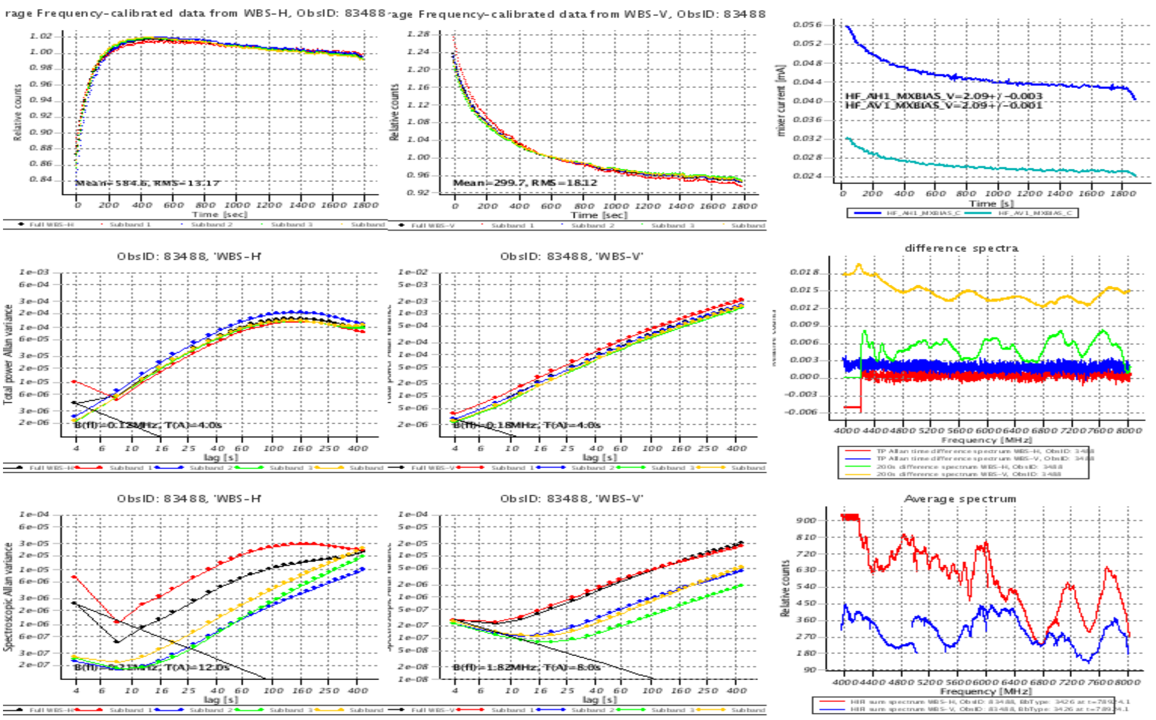


Fig. 25. 814 GHz internal CBB system stability.

5.6.7 B4a LO warm-up (Differential measurement)

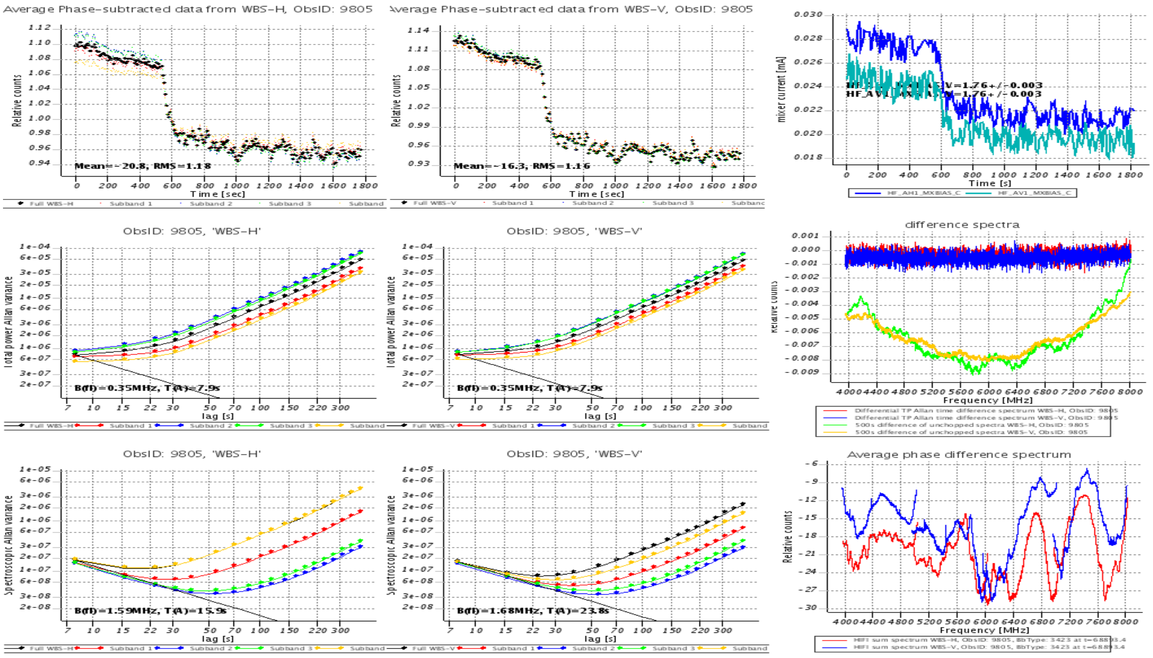


Fig. 26. 982 GHz internal Load differential measurement.

5.6.8 B4a LO warm-up (System measurement)

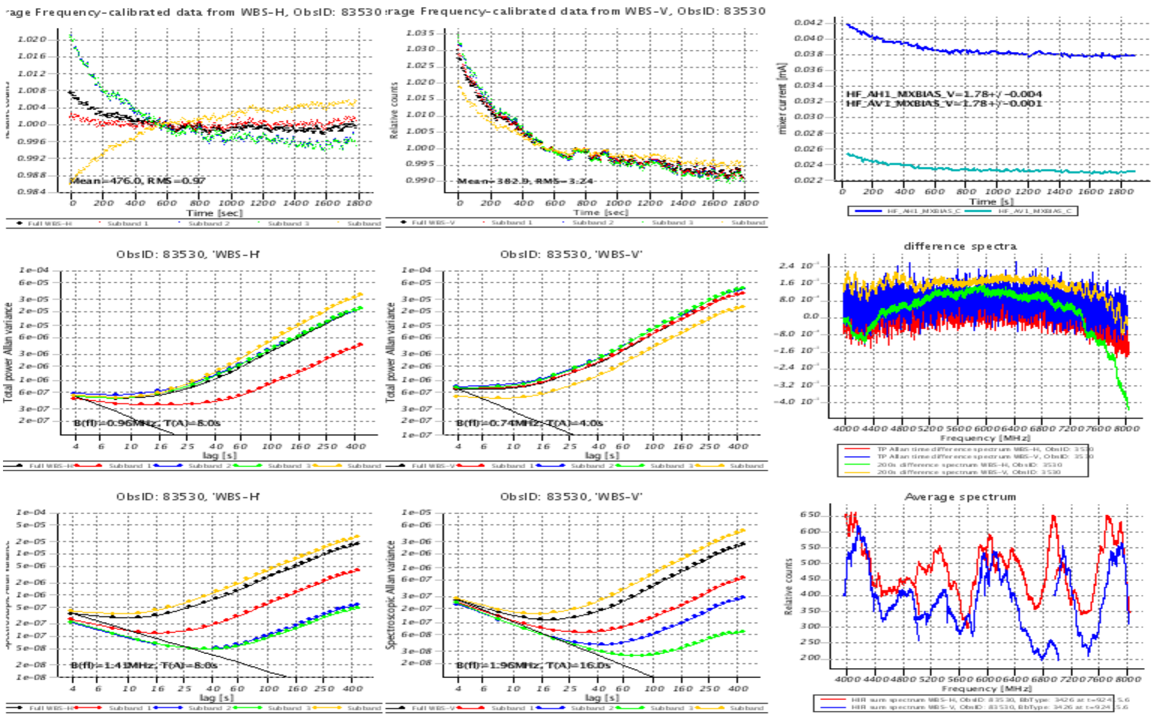


Fig. 27. 995 GHz. internal CBB system stability.

5.6.9 B5b LO warm-up (Differential measurement)

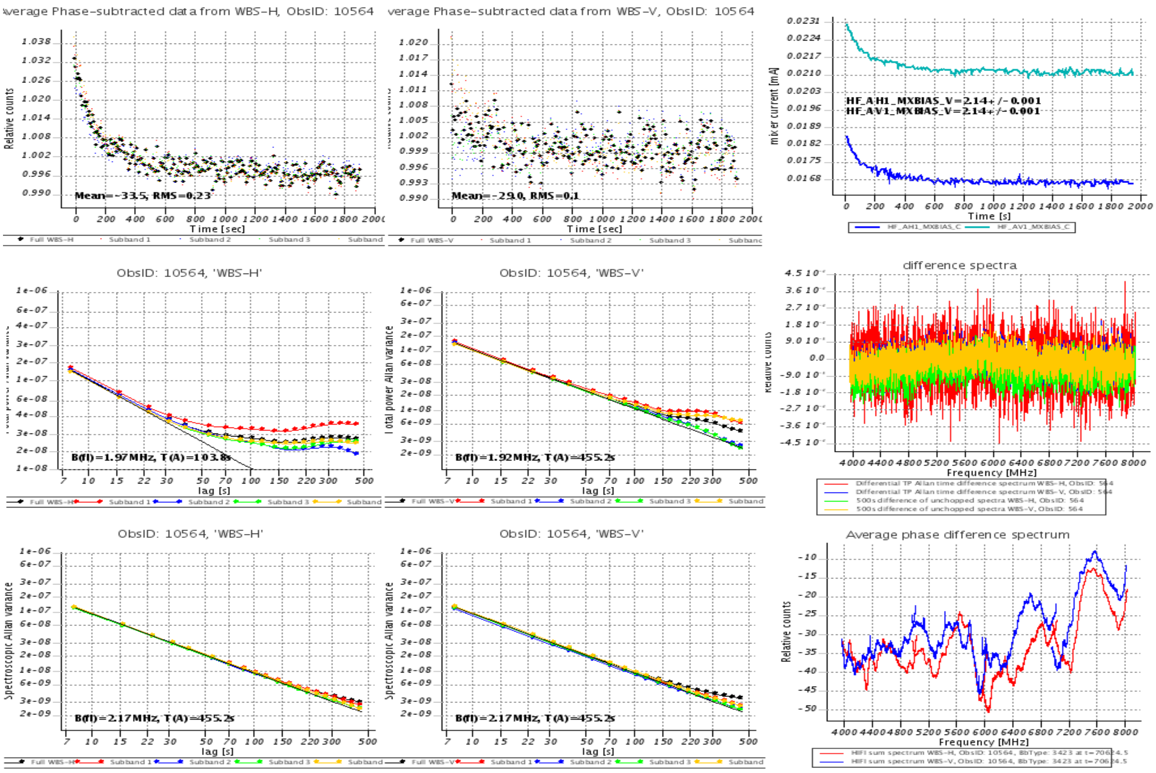


Fig. 28. 1191 GHz internal Load differential measurement.

5.6.10 B5b LO warm-up (System measurement)

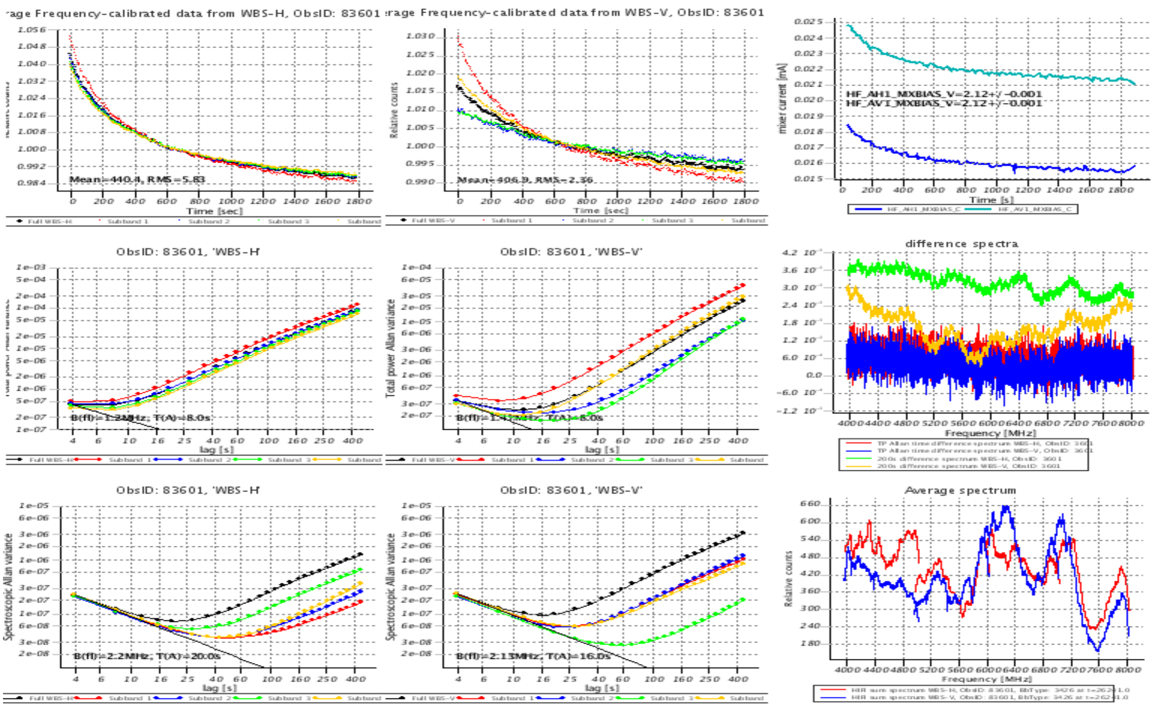


Fig. 29. 1180 GHz internal CBB system stability.

5.6.11 B6b LO warm-up (Differential measurement)

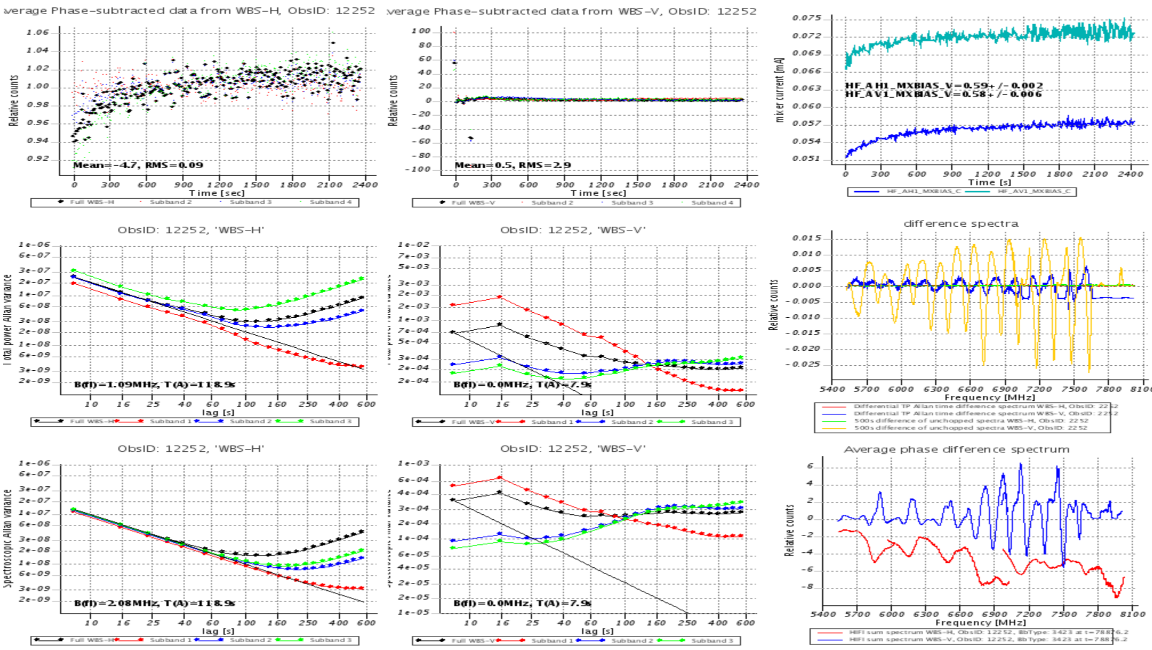


Fig. 30. 1581 GHz, LO power drifts out of usable range during warm-up.

5.6.12 B6b LO warm-up (System measurement)

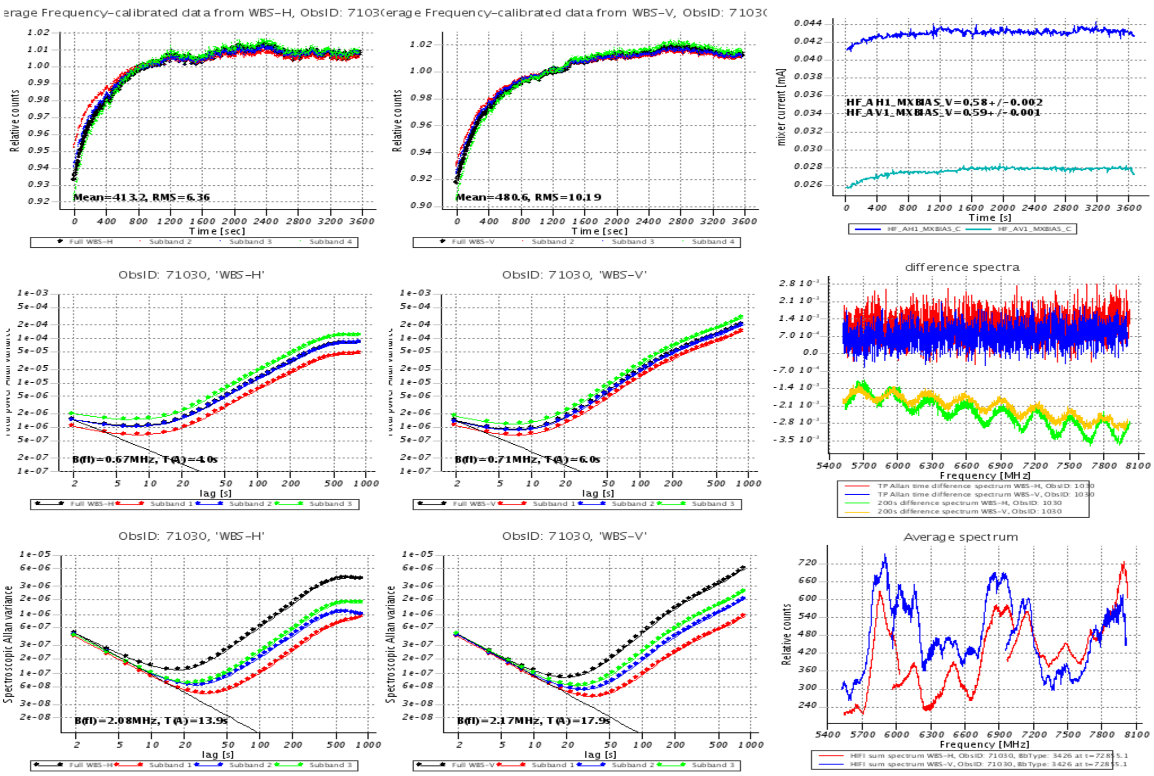


Fig. 31 1599 GHz internal CBB system stability

5.6.13 B7a LO warm-up (Differential measurement)

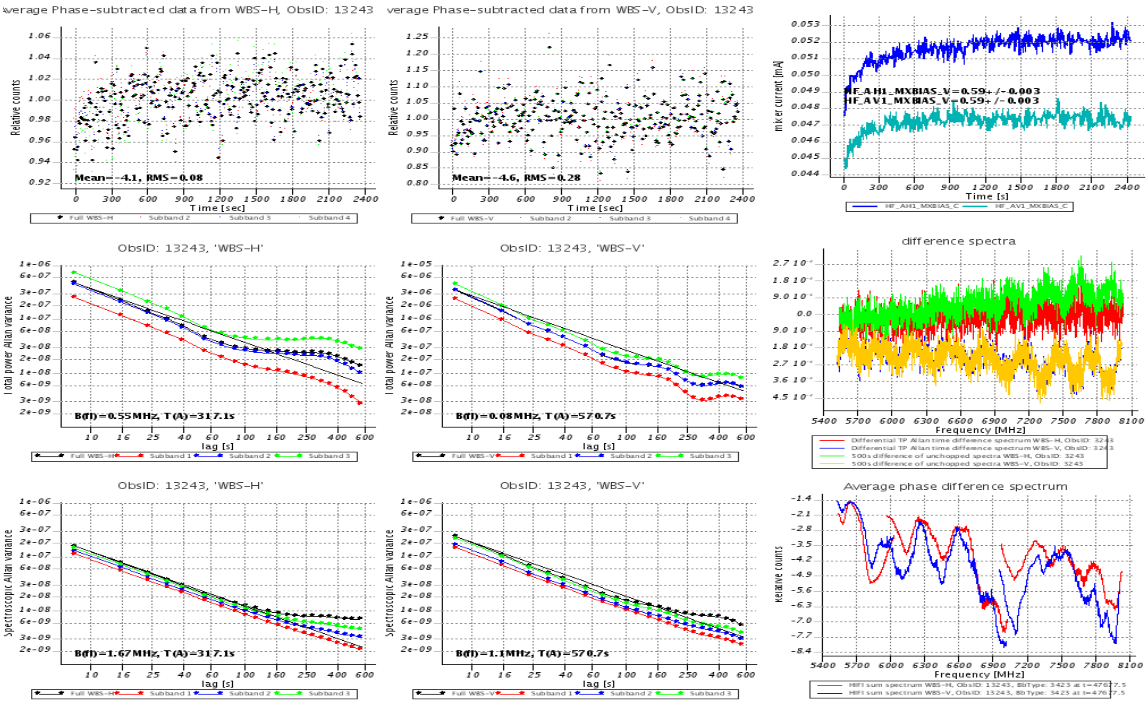


Fig. 32 1716.6 GHz internal Load differential measurement. The IF baseline ripple is due to electrothermal feedback in the IF (standing waves between mixer and IF1).

5.6.14 B7a LO warm-up (System measurement)

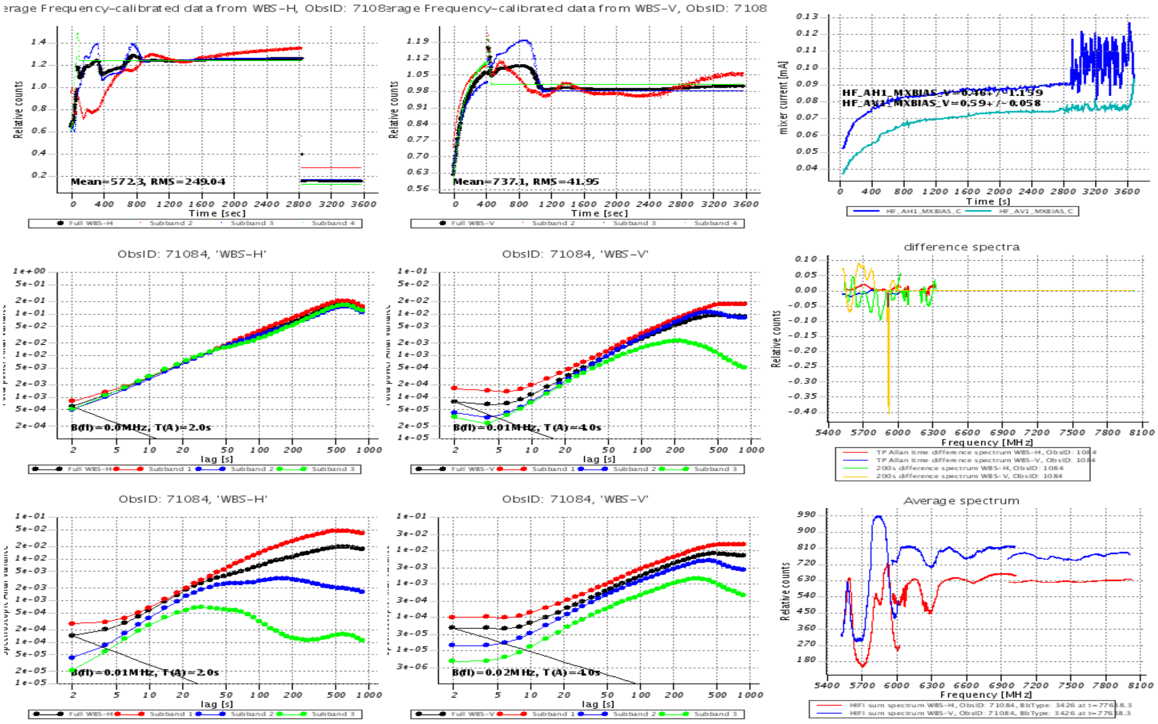


Fig. 33. 1716.6 GHz internal CBB system stability. LO power too low after ~ 35 minutes. Optimal LO is between 40-50 uA. → frequency LO retune needed after an LO turn-on event.

5.6.15 B7b LO warm-up (System measurement)

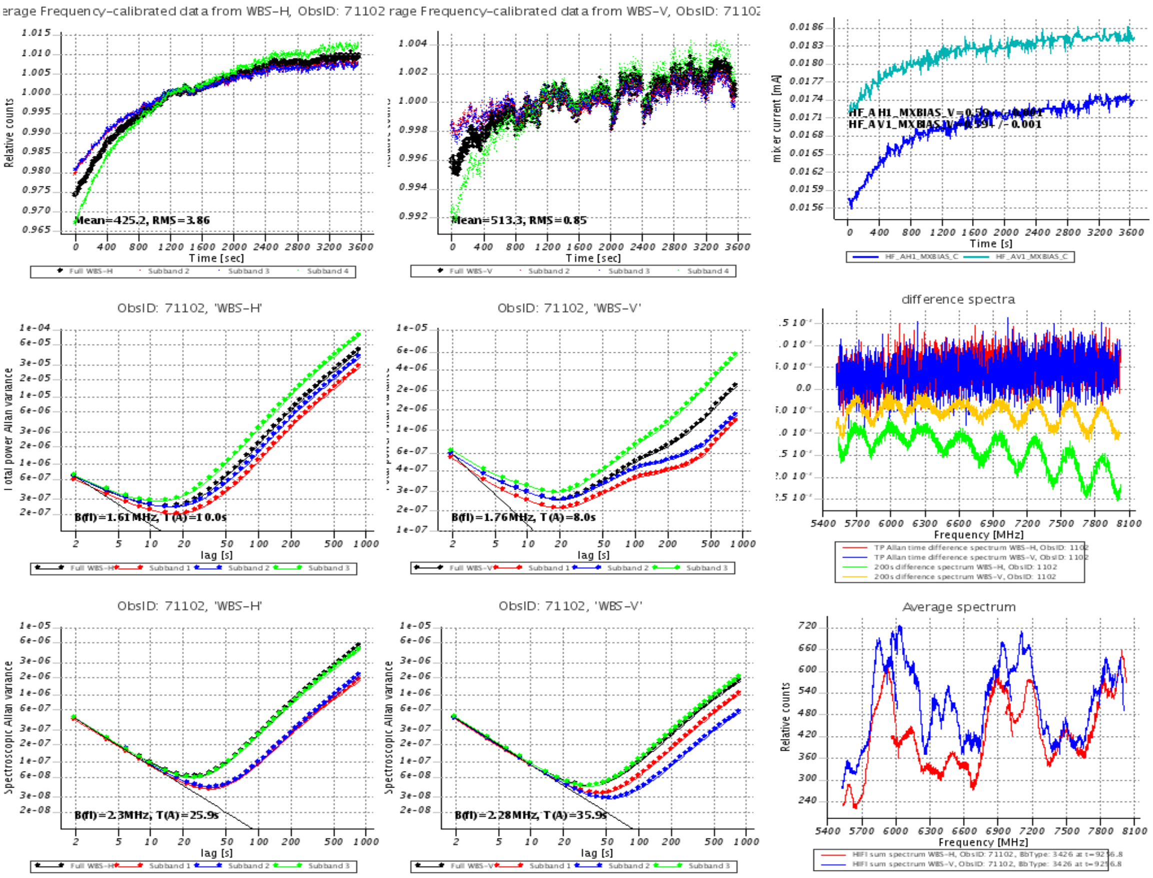


Fig. 34. 1897GHz internal CBB system stability. The IF baseline ripple is due to electrothermal feedback in the IF (standing waves between mixer and IF1).

5.7 System Stability per LO sub-band

5.7.1 B1a (Beamsplitter band)

5.7.1.1 WBS B1a

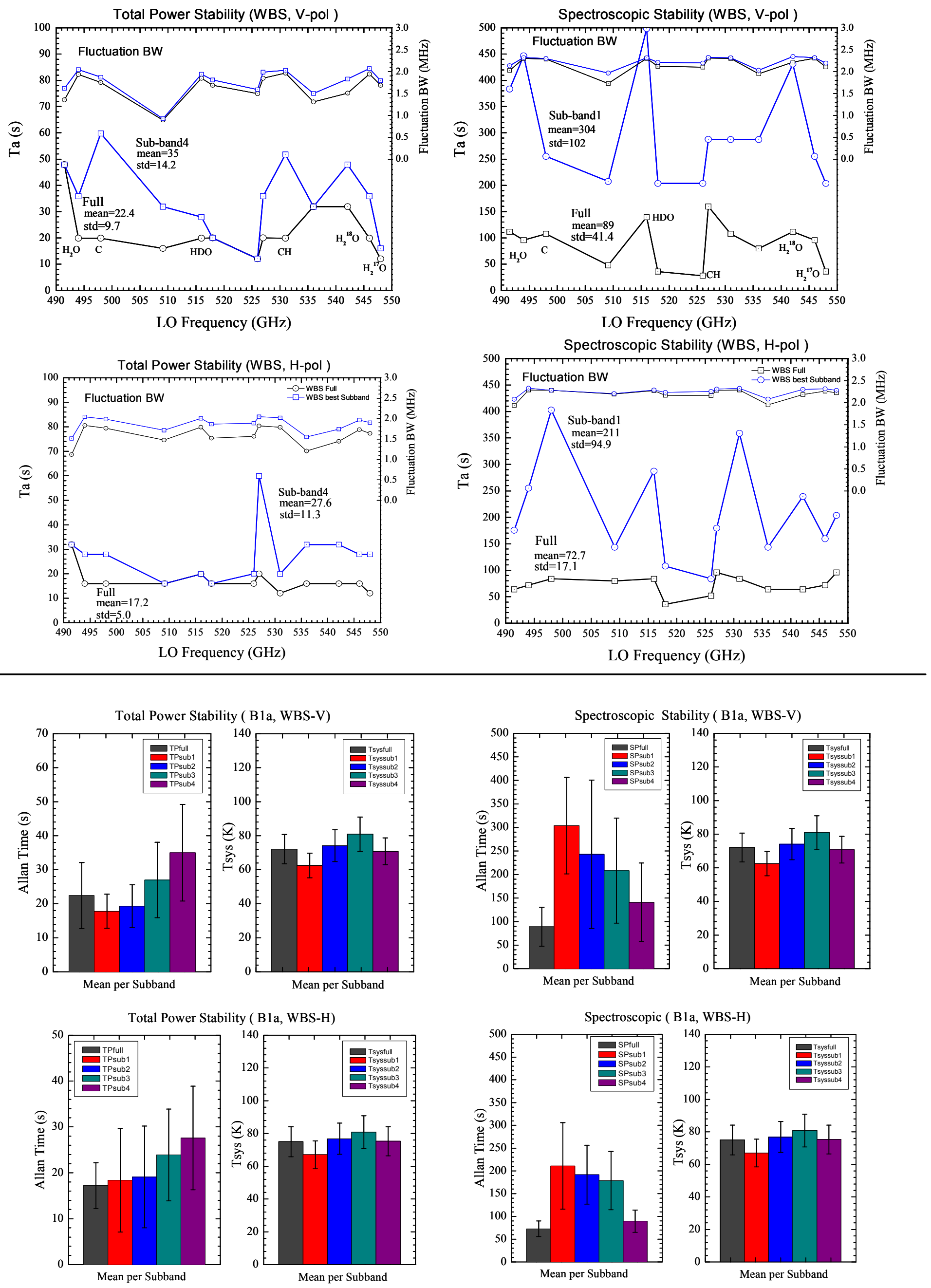


Fig 35. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per WBS sub-band. Note the difference in spectroscopic stability per WBS sub-band vs. Full (8000ch).

5.7.1.2 HRS B1a

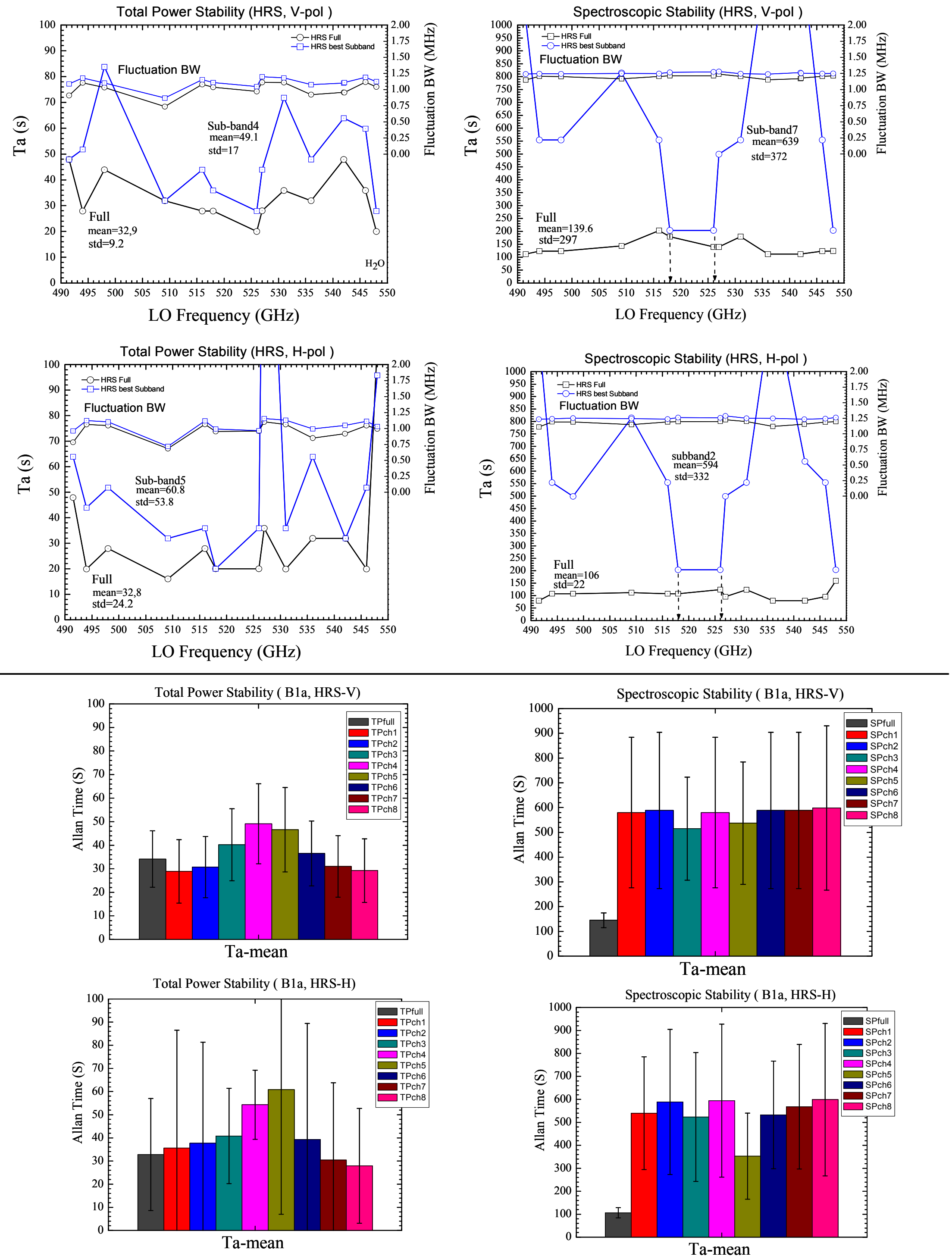


Fig 36 Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full. The exception is the region 518-526 GHz where there maybe some excess LO noise.

5.7.1.3 Tsys B1a

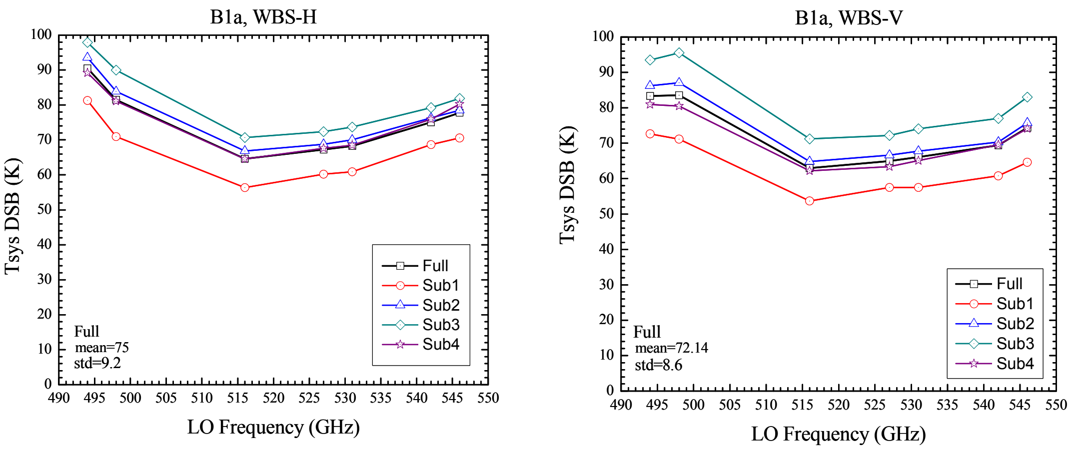


Fig. 37. System noise temperature per polarization. B1 is a beamsplitter band. 4-5 GHz channel (WBS sub-band1 is the most sensitive).

5.7.2 B1b (beamsplitter band).

5.7.2.1 WBS B1b

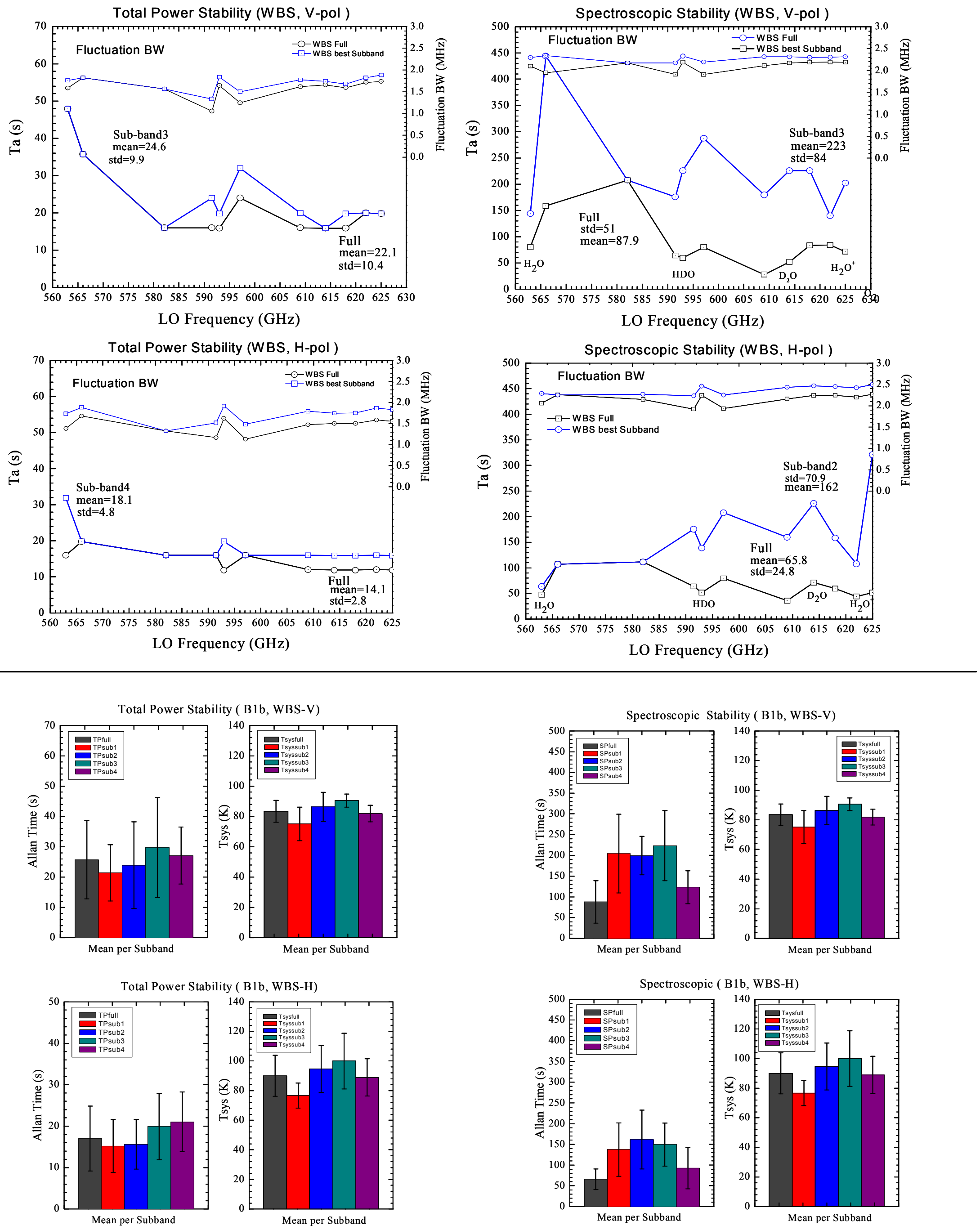


Fig 38 Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band.

5.7.2.2 HRS B1b

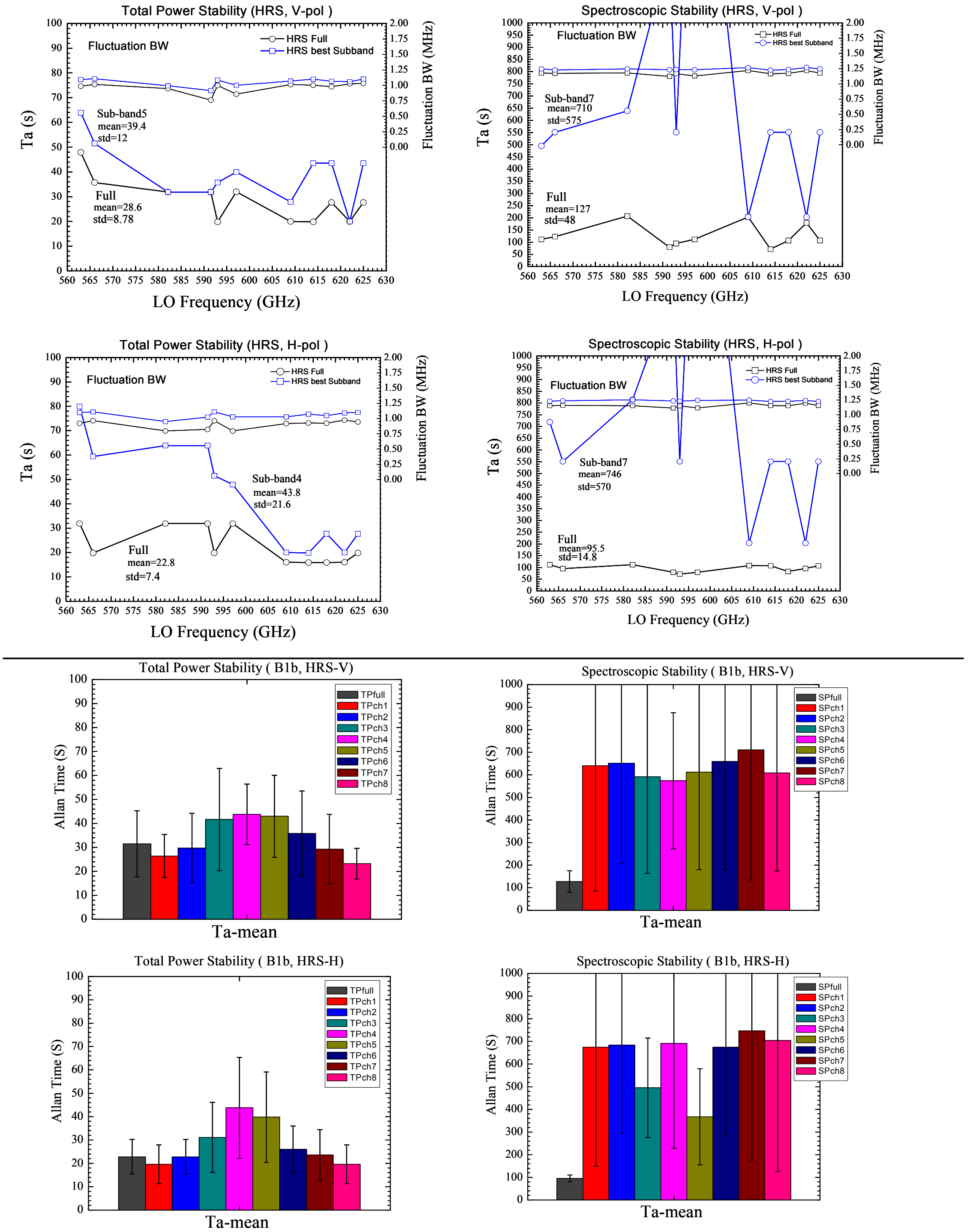


Fig. 39 Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.2.3 HRSfast B1b

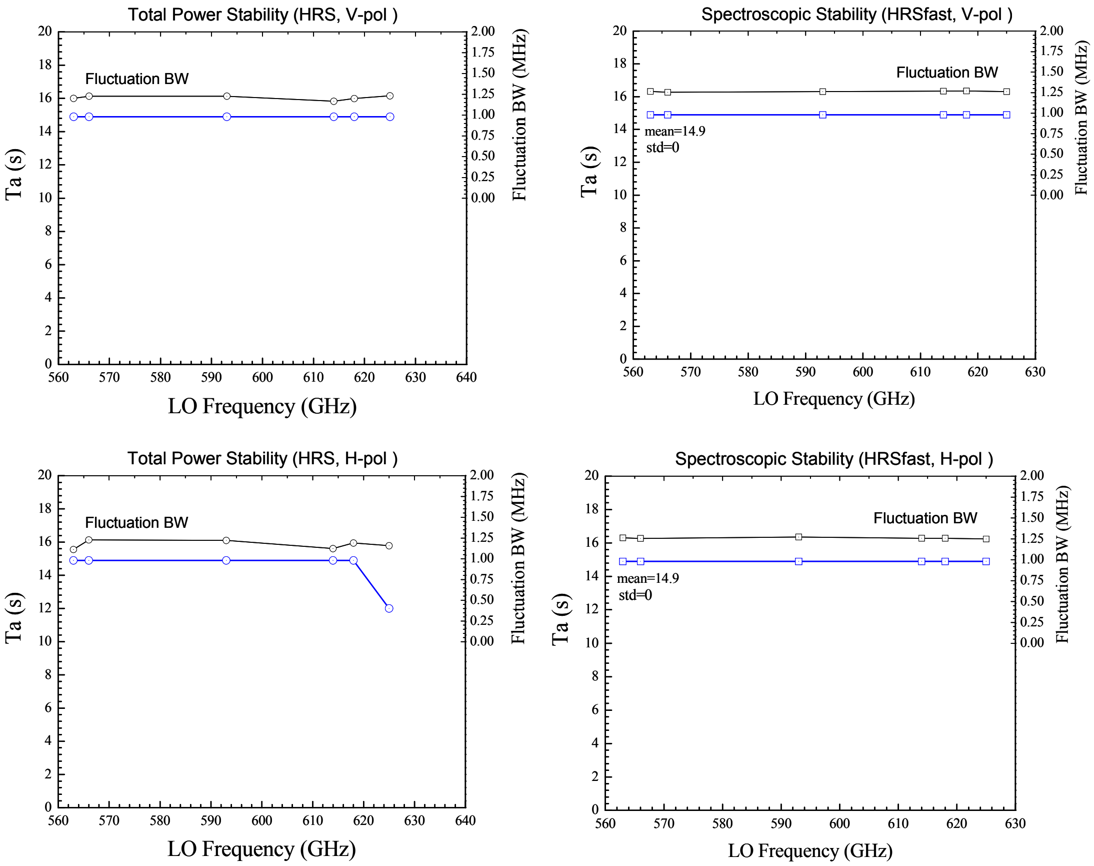


Fig. 36 Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.2.4 Tsys B1b

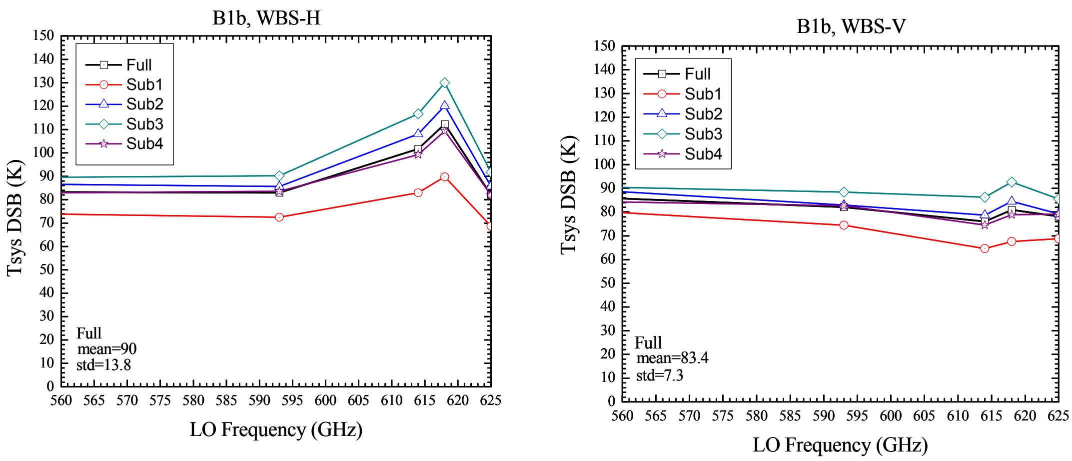


Fig. 40 System noise temperature per polarization. B1 is a beamsplitter band. 4-5 GHz channel (sub-band1 is the most sensitive).

5.7.3 B2a (beamsplitter band)

5.7.3.1 WBS B2a

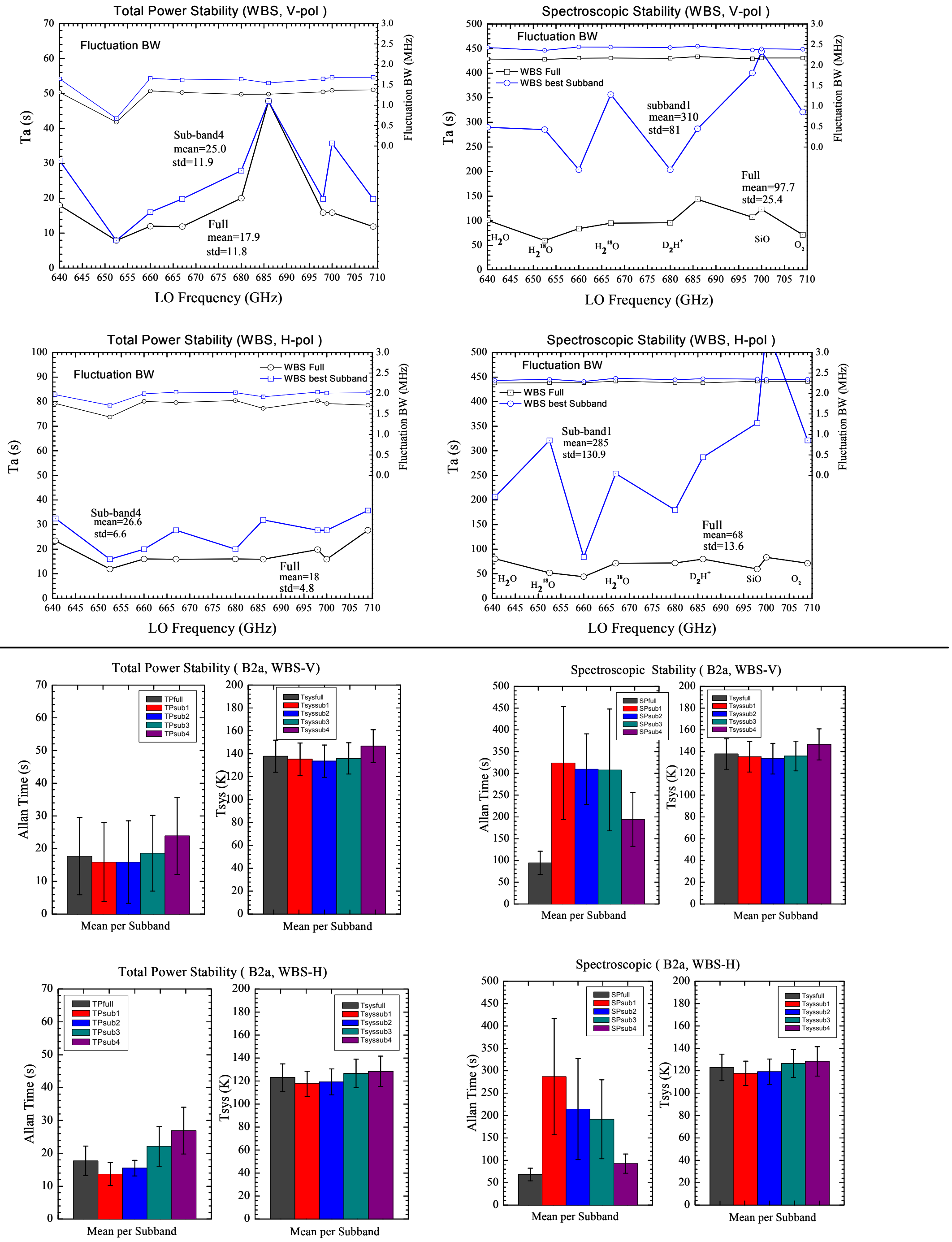


Fig. 41. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. Note the difference in spectroscopic stability per WBS sub-band vs. Full (8000ch).

5.7.3.2 HRS B2a

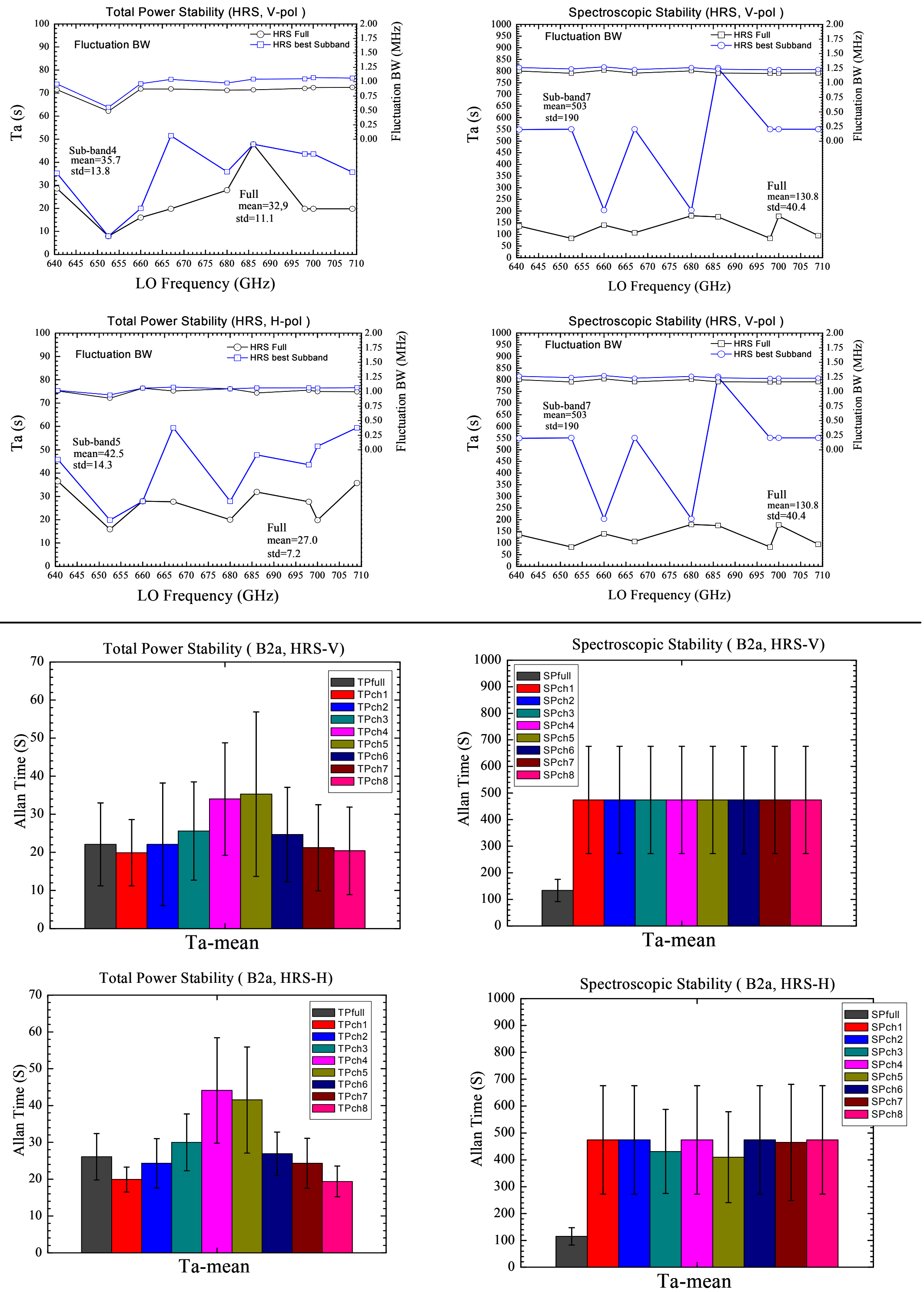


Fig 42. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.3.3 HRSfast B2a

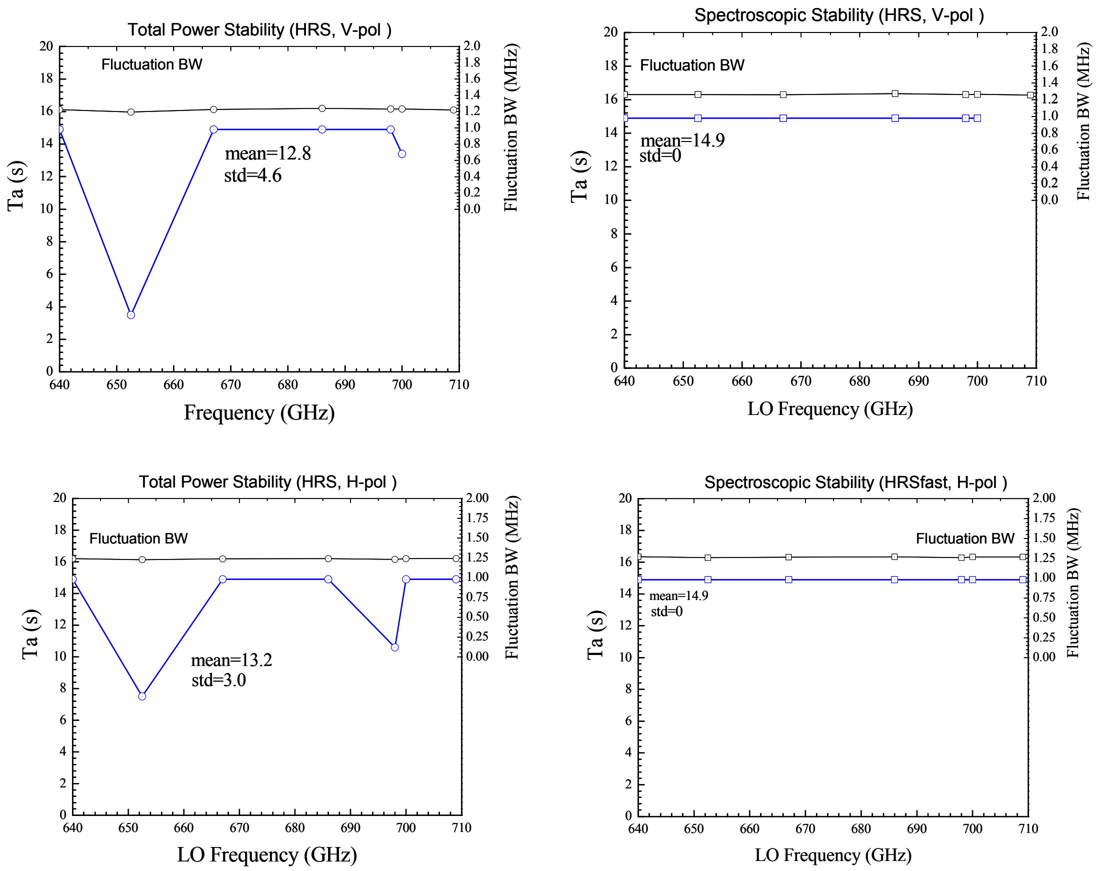


Fig 43. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.3.4 Tsys B2a

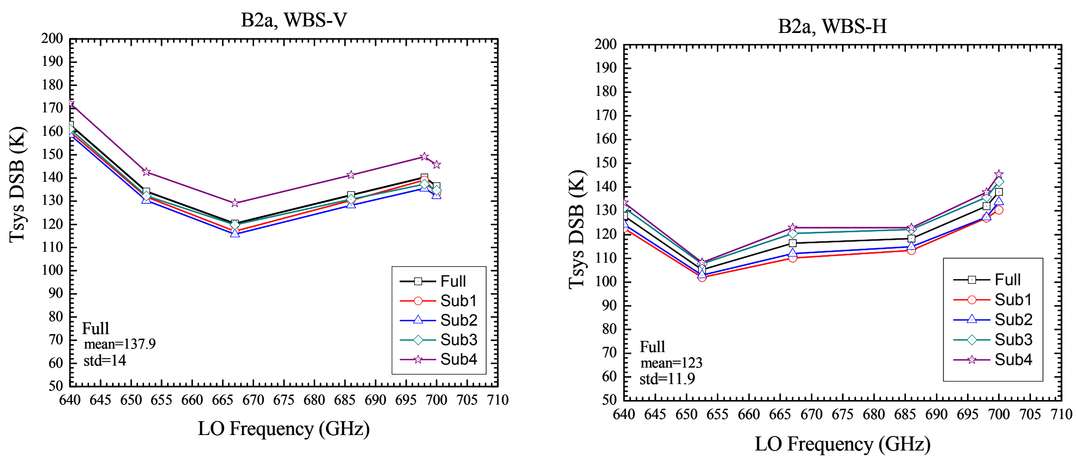
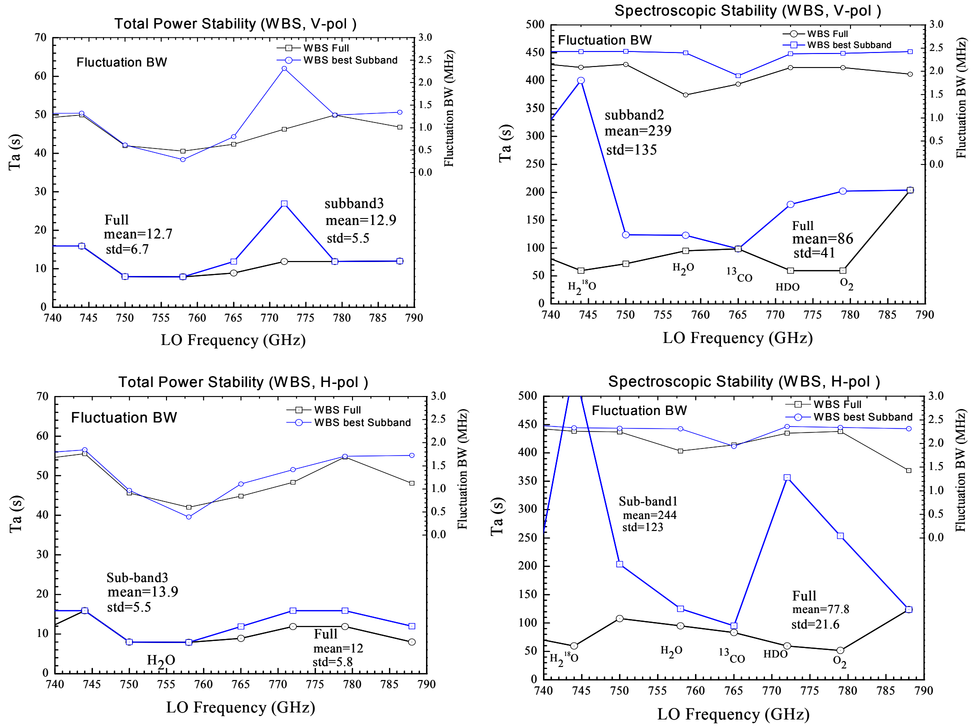


Fig 44. System noise temperature per polarization. B2 is a beamsplitter band.

5.7.4 B2b (beamsplitter band)

5.7.4.1 WBS B2b



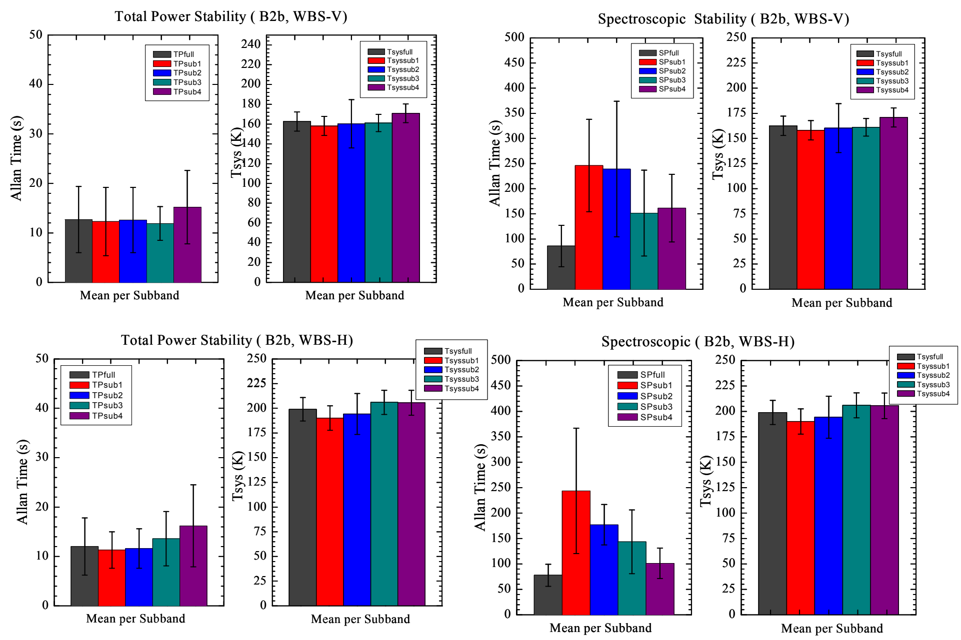


Fig 45. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. Note the difference in spectroscopic stability per WBS sub-band vs. Full (8000ch).

5.7.4.2 HRS B2b

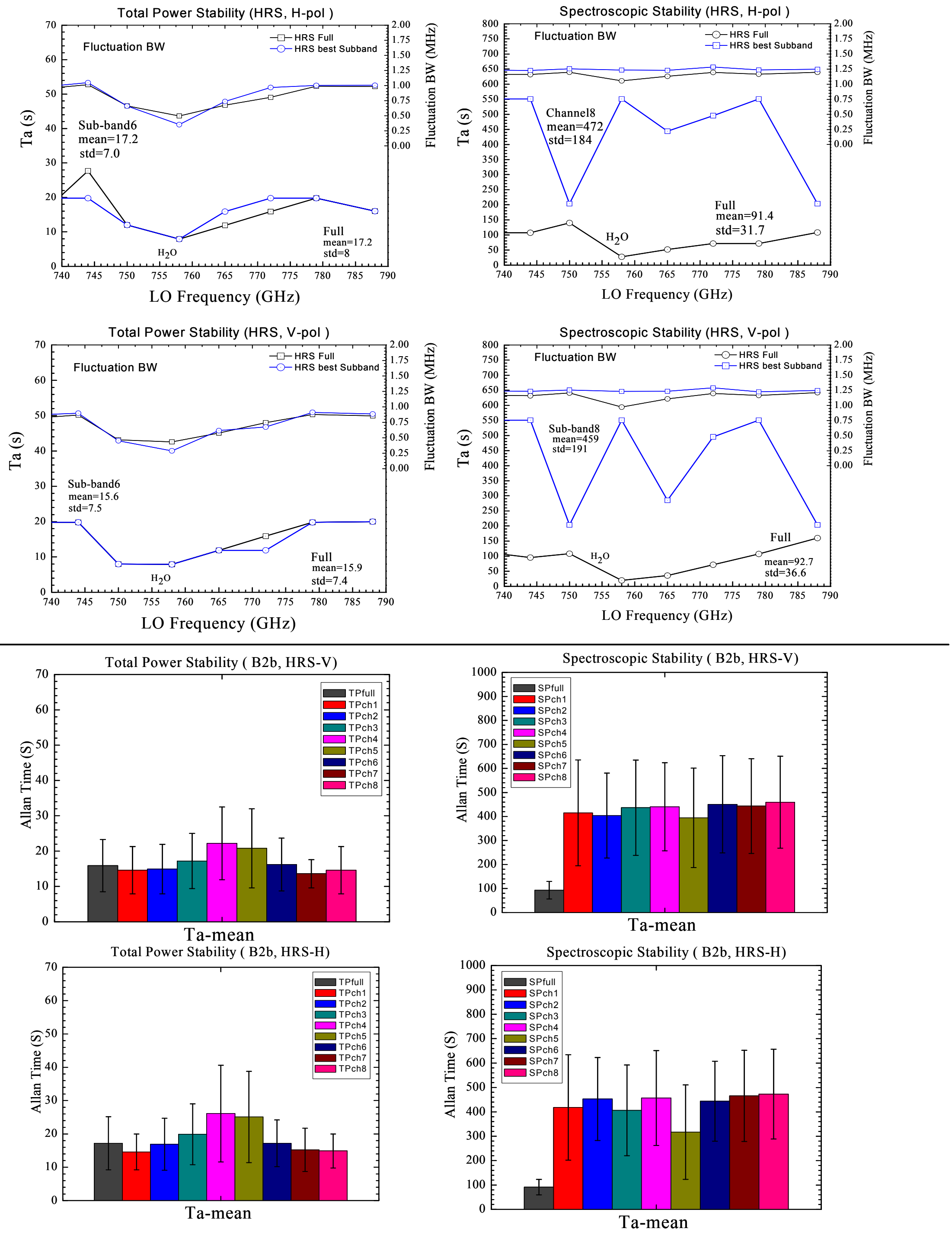


Fig 46. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.4.3 HRSfast B2b

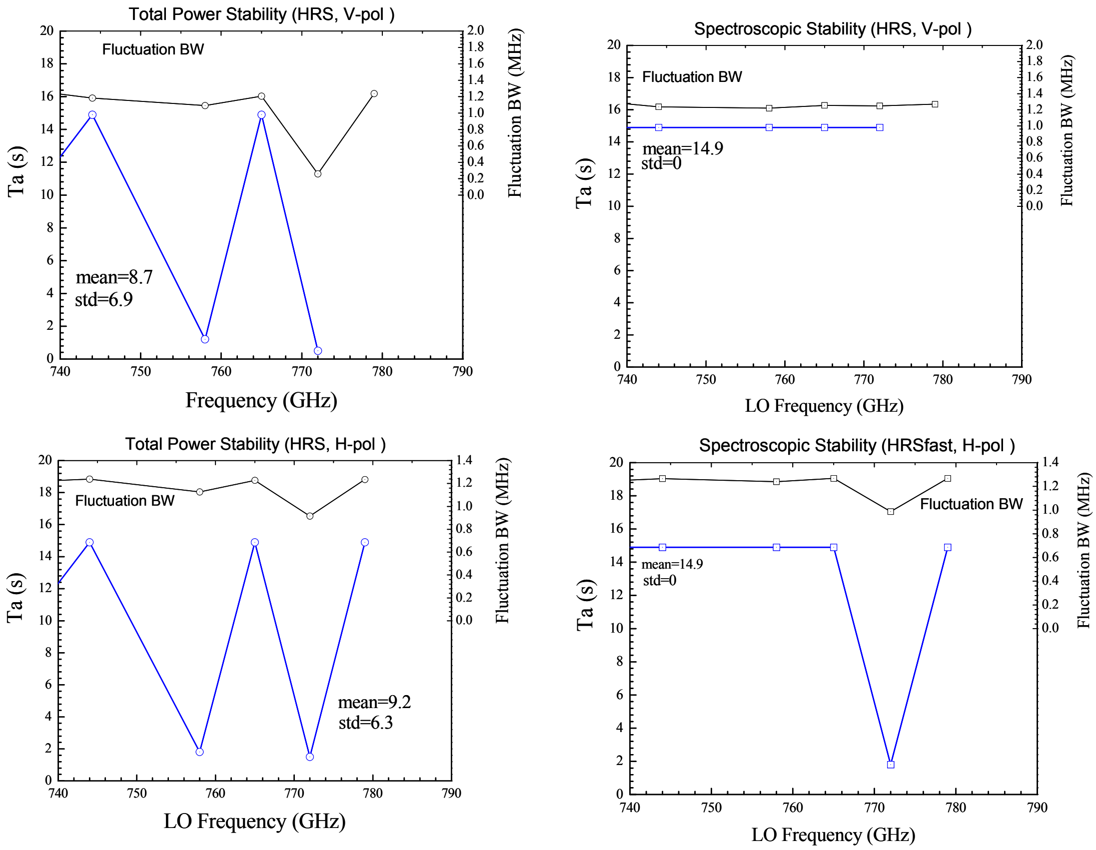


Fig. 47. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.4.4 Tsys B2b

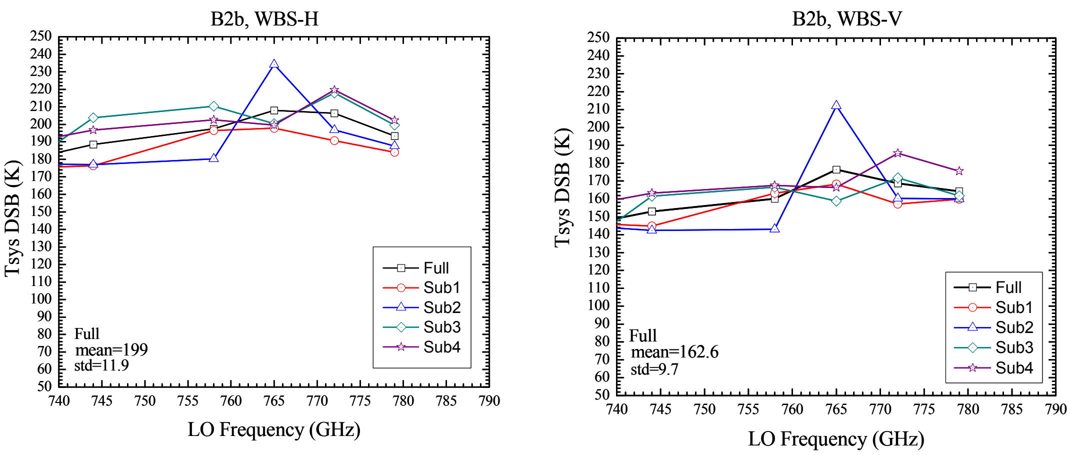


Fig. 48. System noise temperature per polarization. B2 is a beamsplitter band.

5.7.5 B3a (diplexer band)

5.7.5.1 WBS B3a

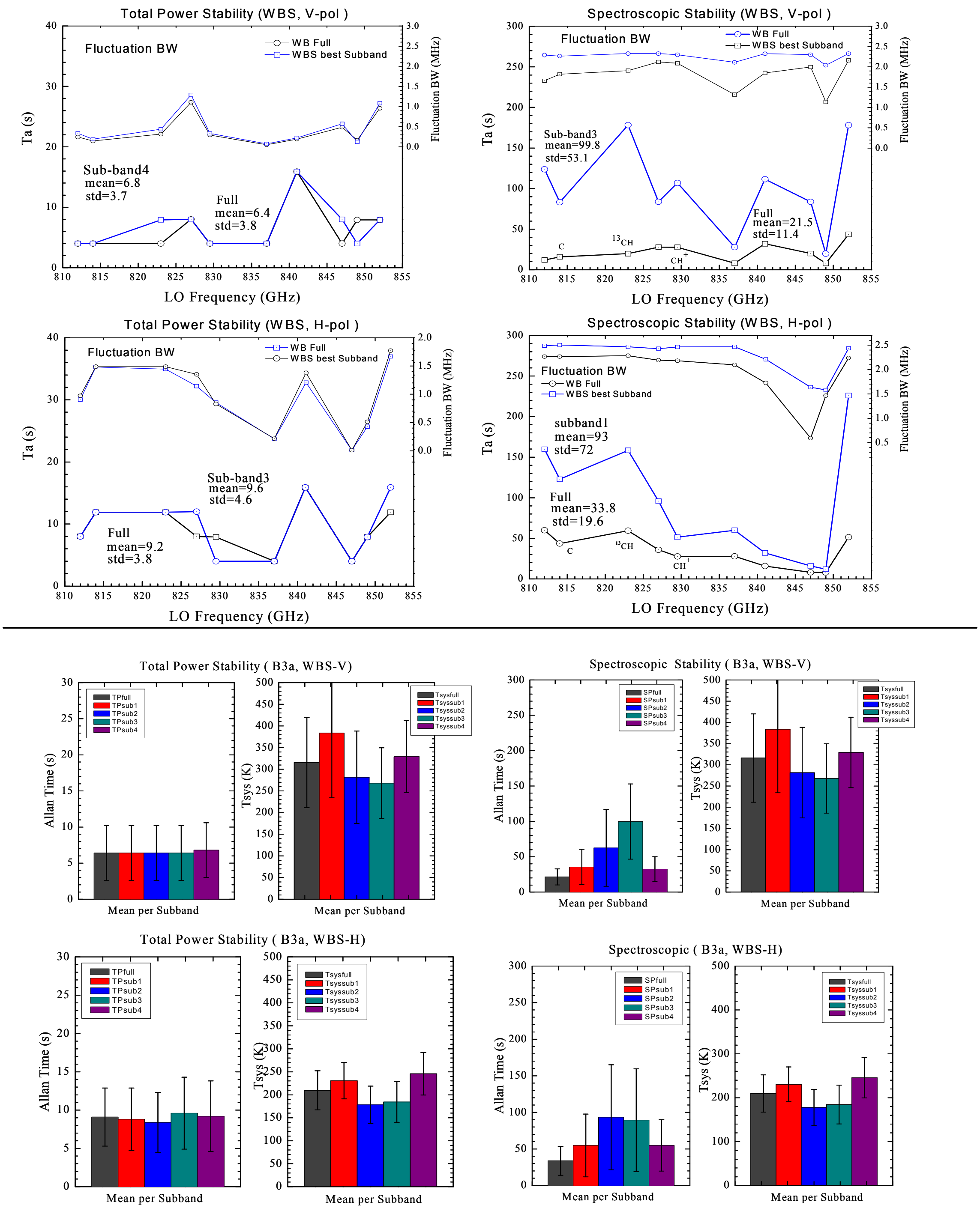


Fig 49. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 2, 3 are clearly the best.

5.7.5.2 HRS B3a

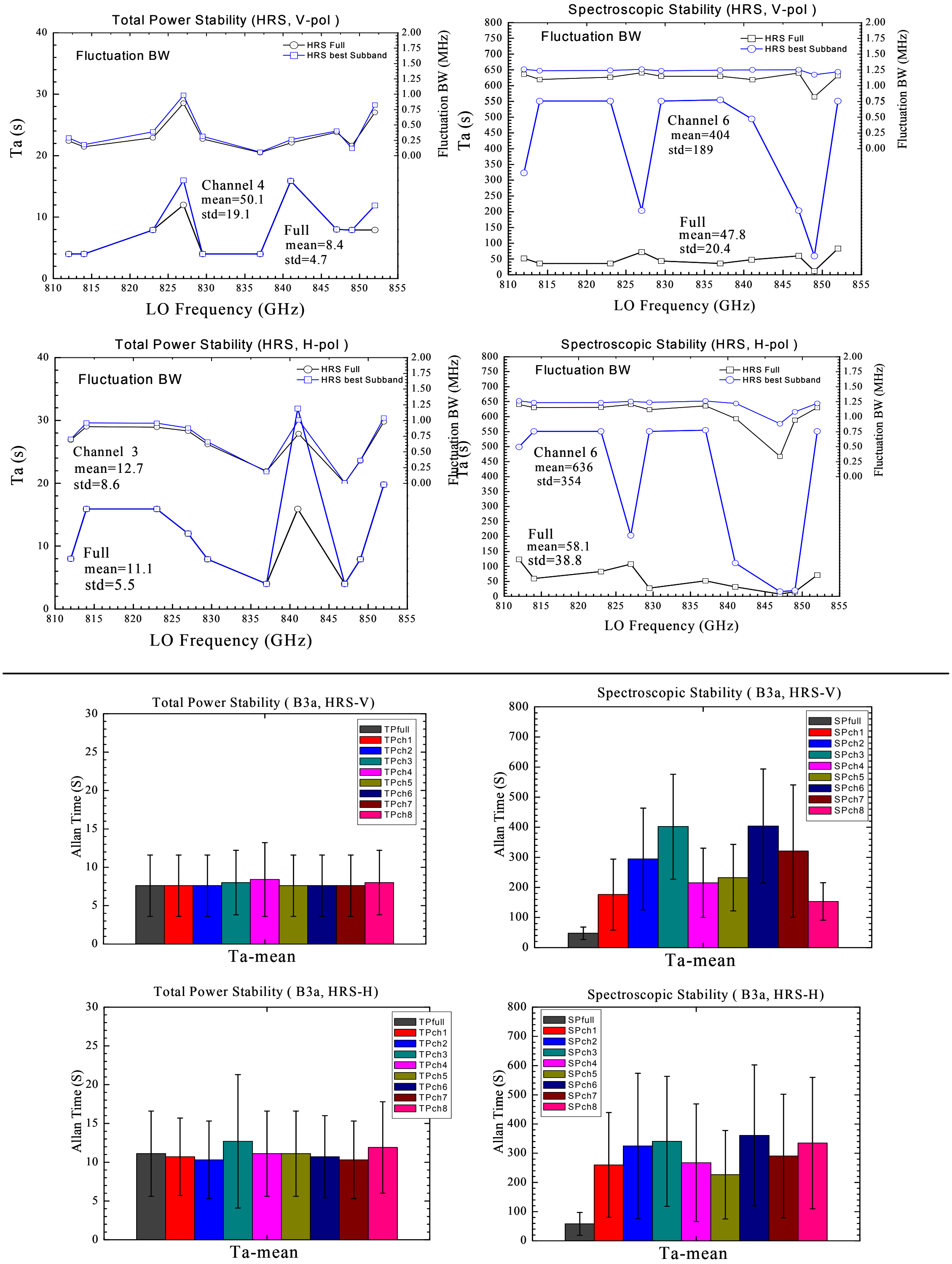


Fig. 50. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.5.3 HRSfast B3a

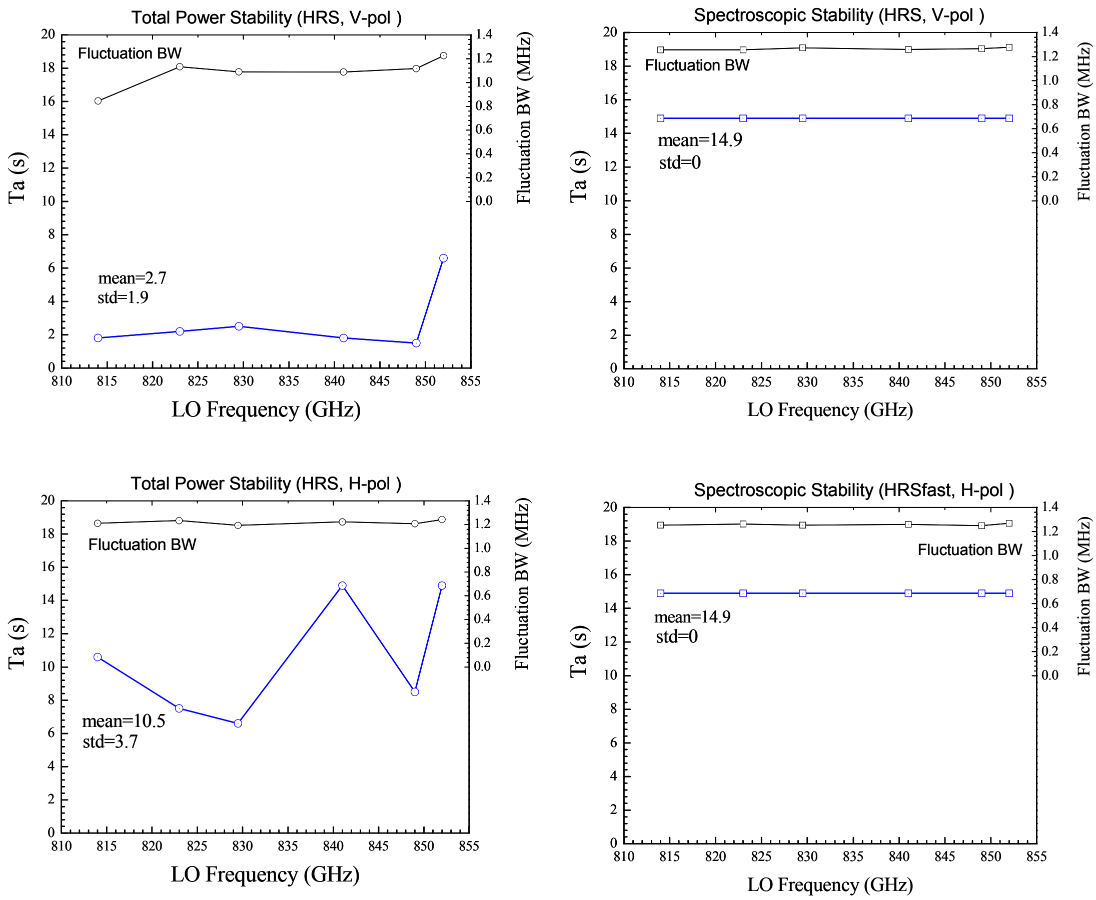


Fig. 51 Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.5.4 Tsys B3a

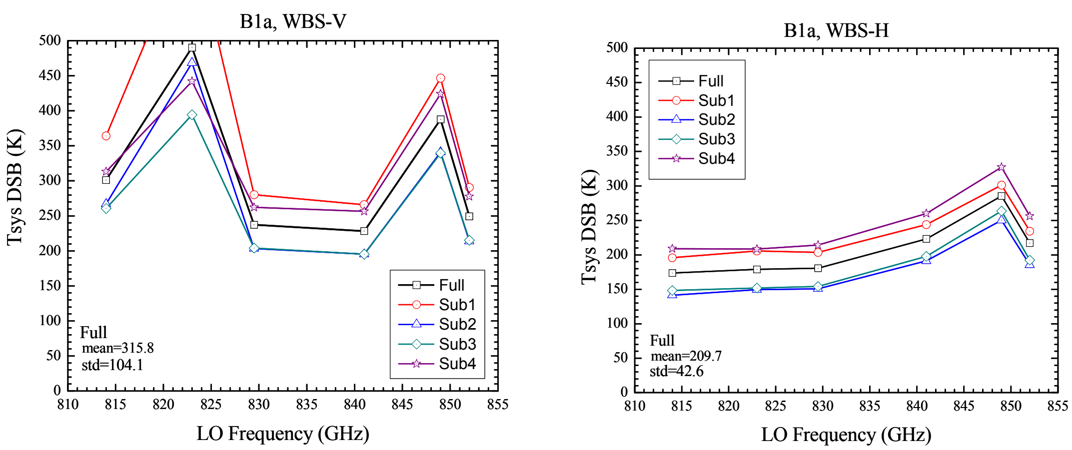


Fig 52. System noise temperature per polarization. B3 is a diplexer band. Polarization dependent behavior of WBS-V at 820 GHz unclear.

5.7.6 B3b (diplexer band).

5.7.6.1 WBS B3b

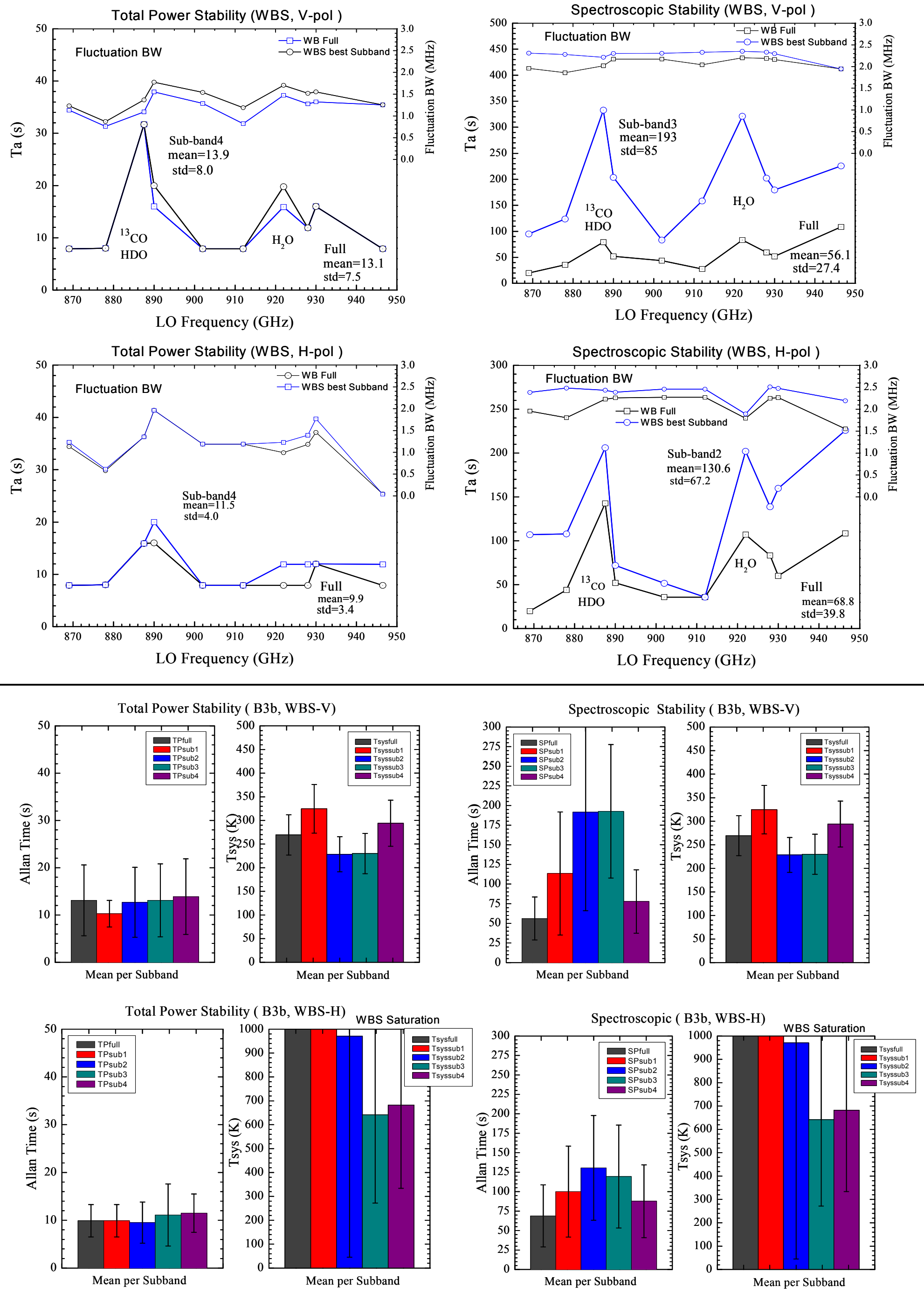


Fig 53. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 2, 3 are clearly the best.

5.7.6.2 HRS B3b

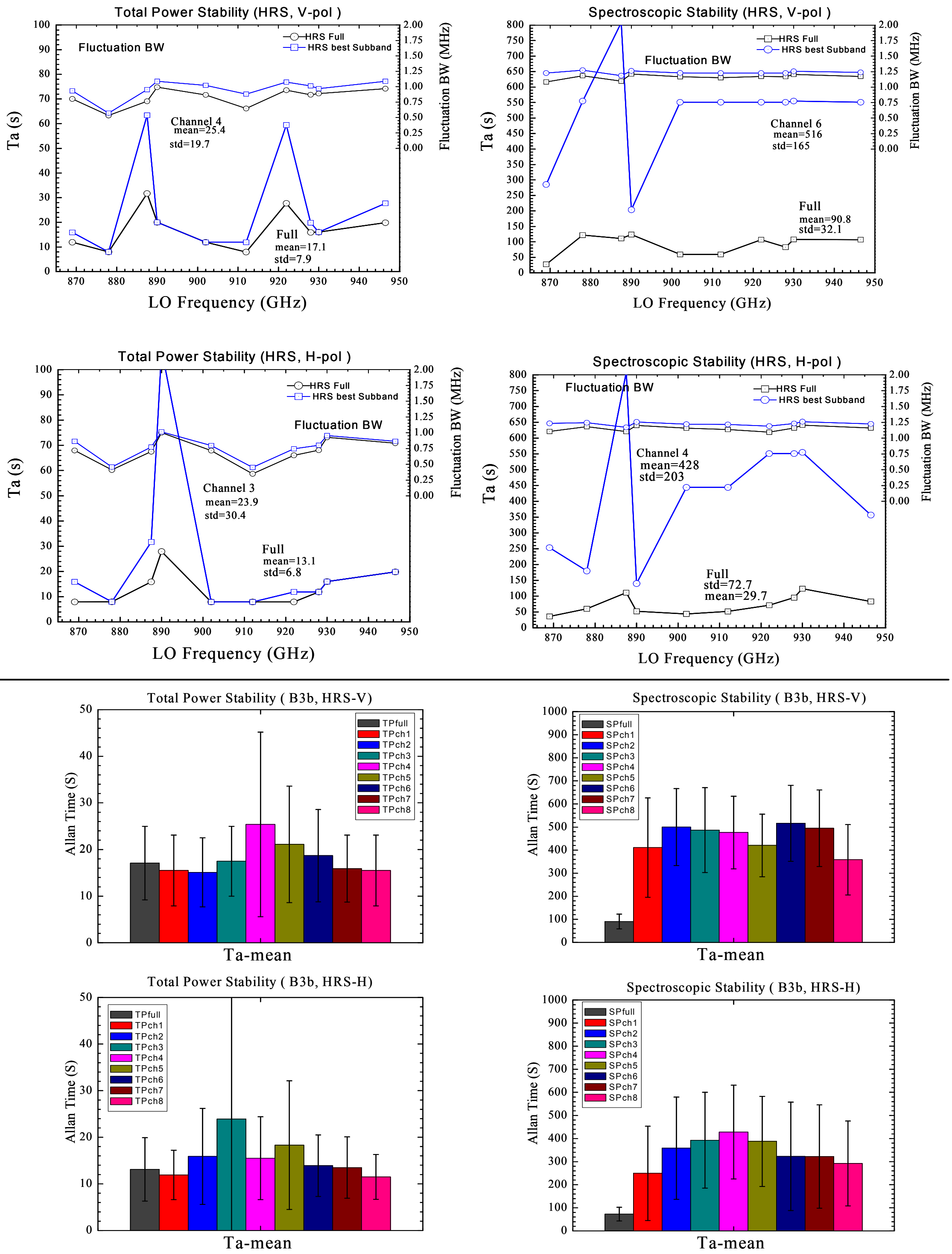


Fig 54. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.6.3 HRSfast B3b

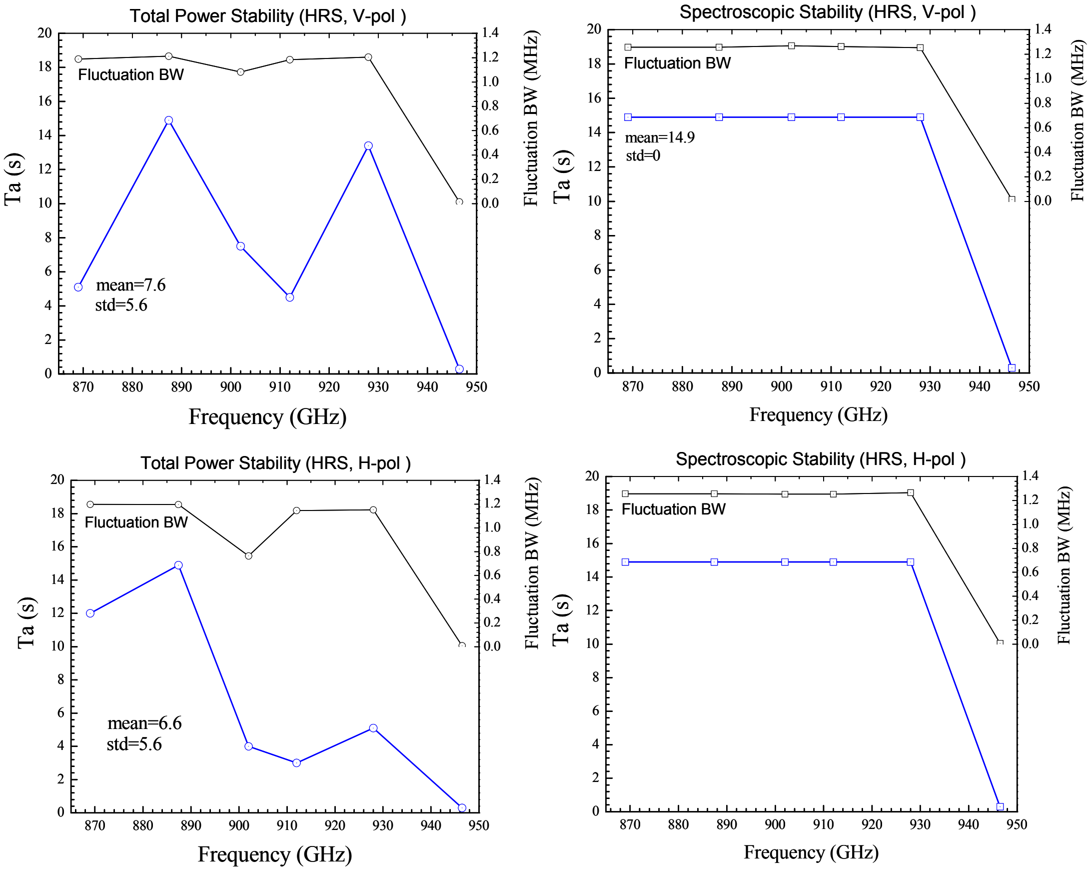


Fig. 55. Single HRS channel (1 GHz), fast readout at 6 Hz.

5.7.6.4 Tsys B3b

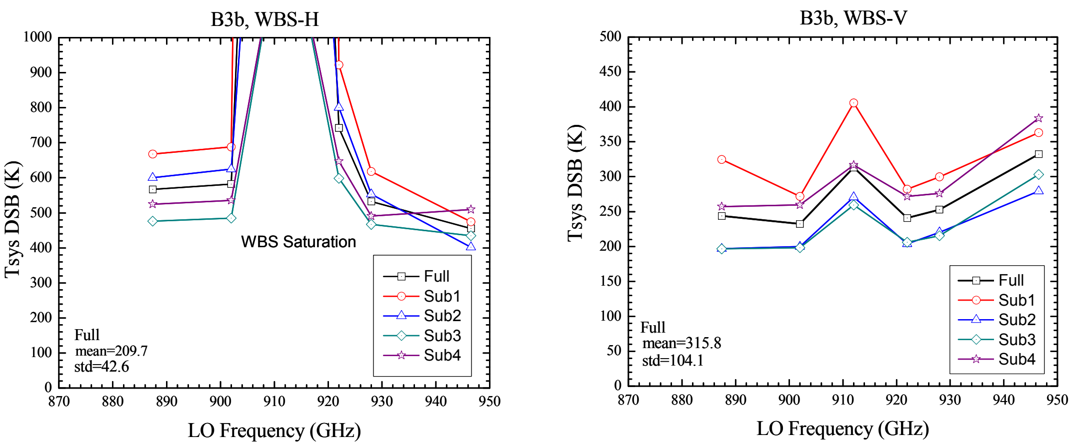


Fig. 56. System noise temperature per polarization. B3 is a diplexer band. Note the polarized excess noise at 912GHz.

5.7.7 B4a (diplexer band)

5.7.7.1 WBS B4a

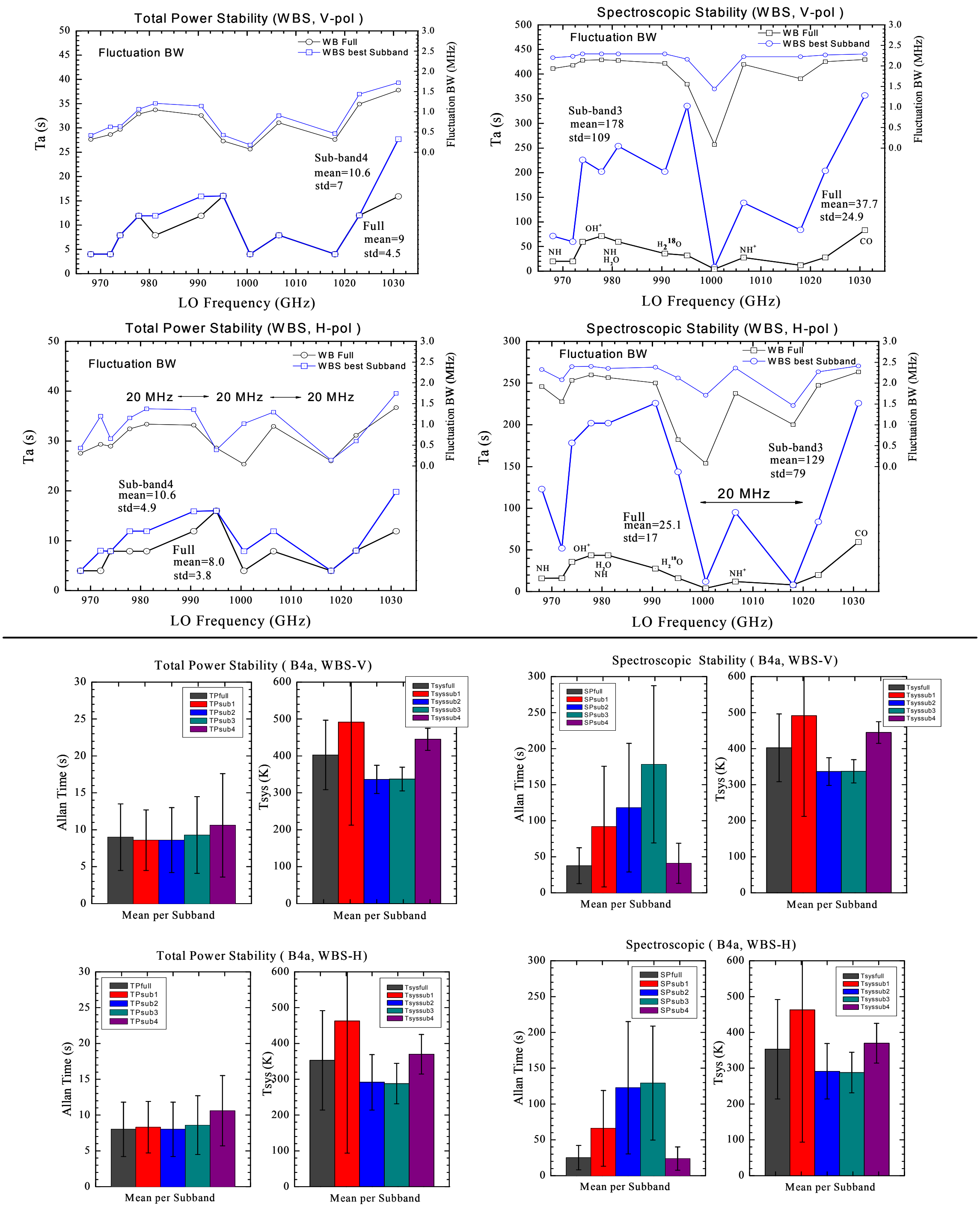


Fig. 57. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 2, 3 are clearly the best.

5.7.7.2 HRS B4a

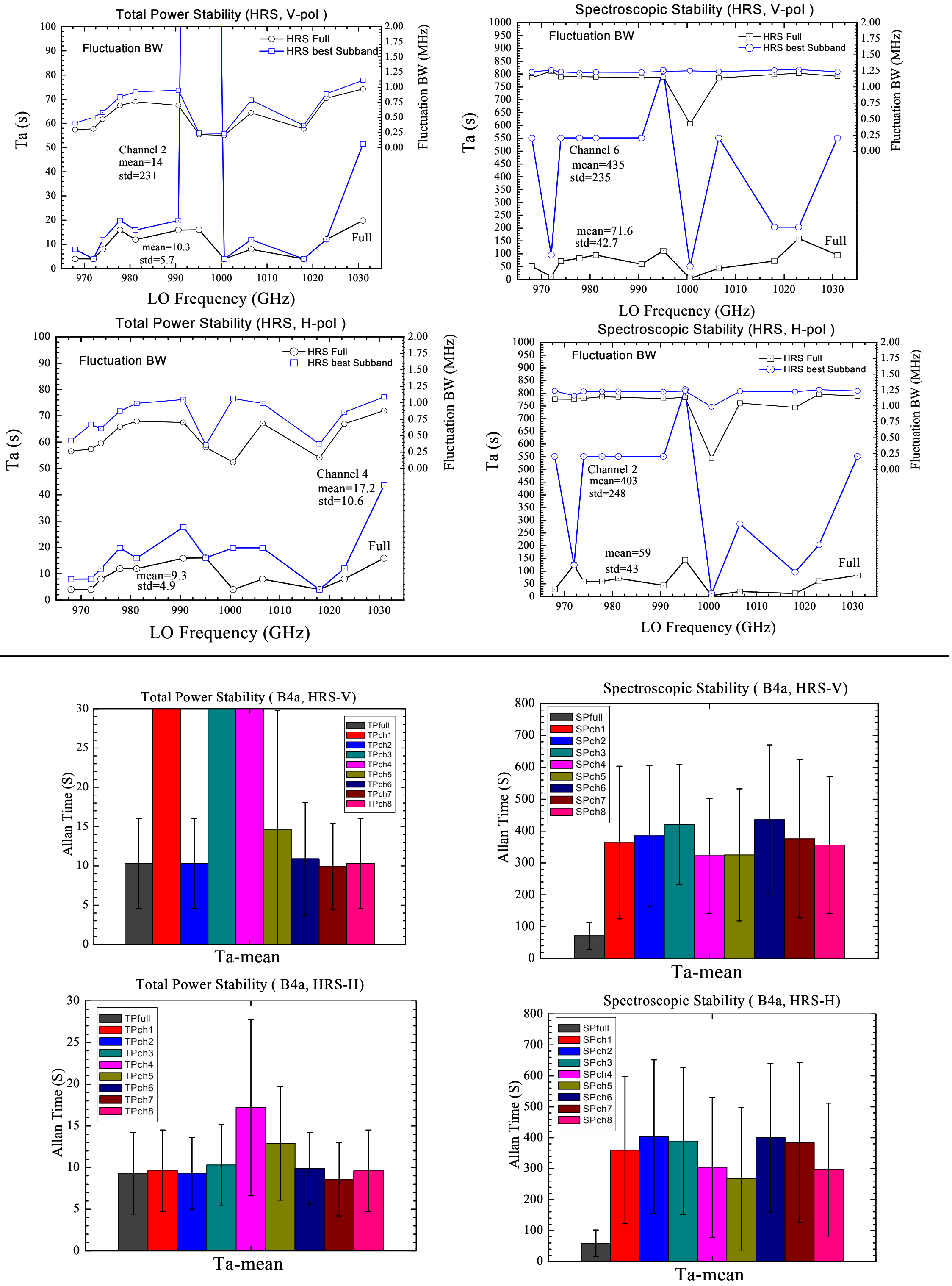


Fig. 58. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.7.3 HRSfast B4a

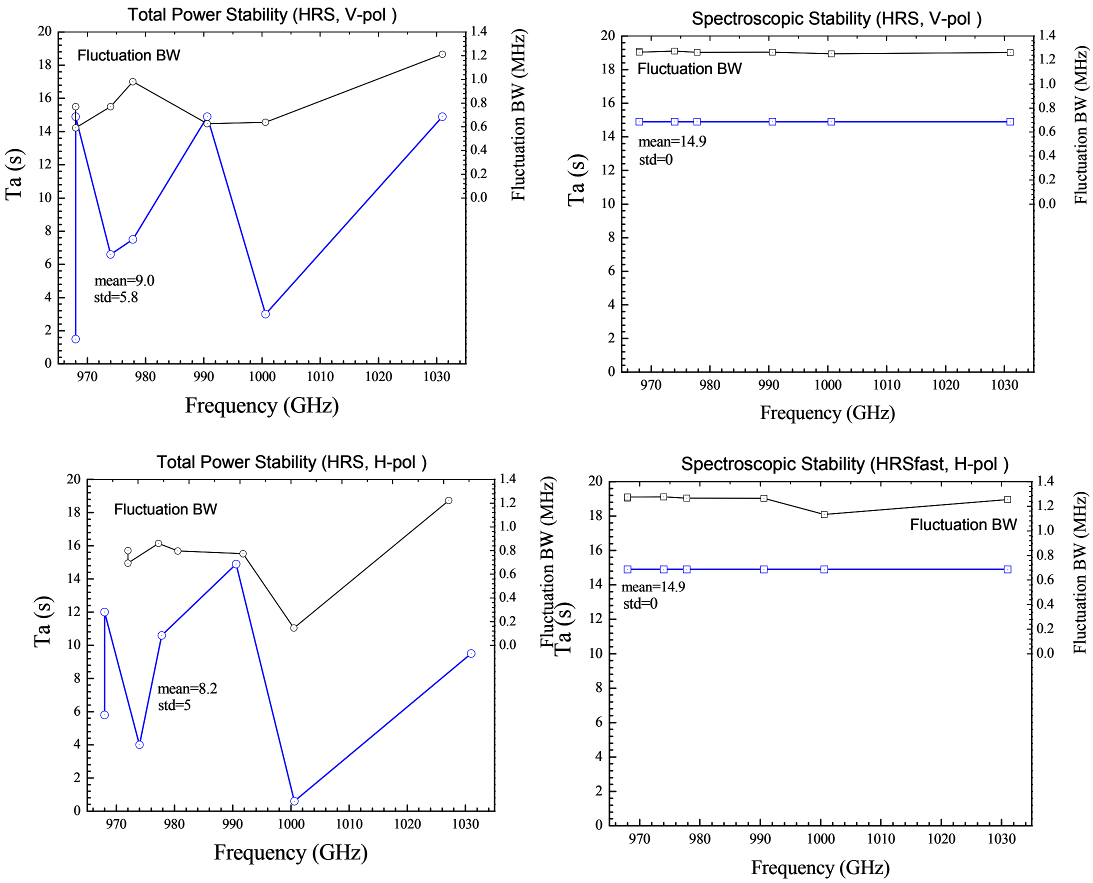


Fig. 59. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.7.4 Tsys B4a

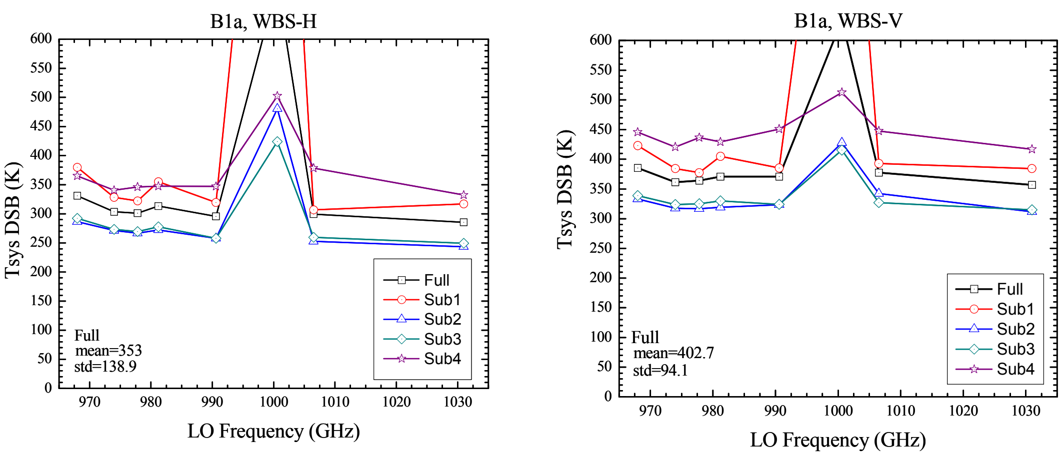


Fig. 60. System noise temperature per polarization. B4 is a diplexer band. Note severe excess noise at 1000.6 GHz.

5.7.8 B4b (diplexer band)

5.7.8.1 WBS B4b

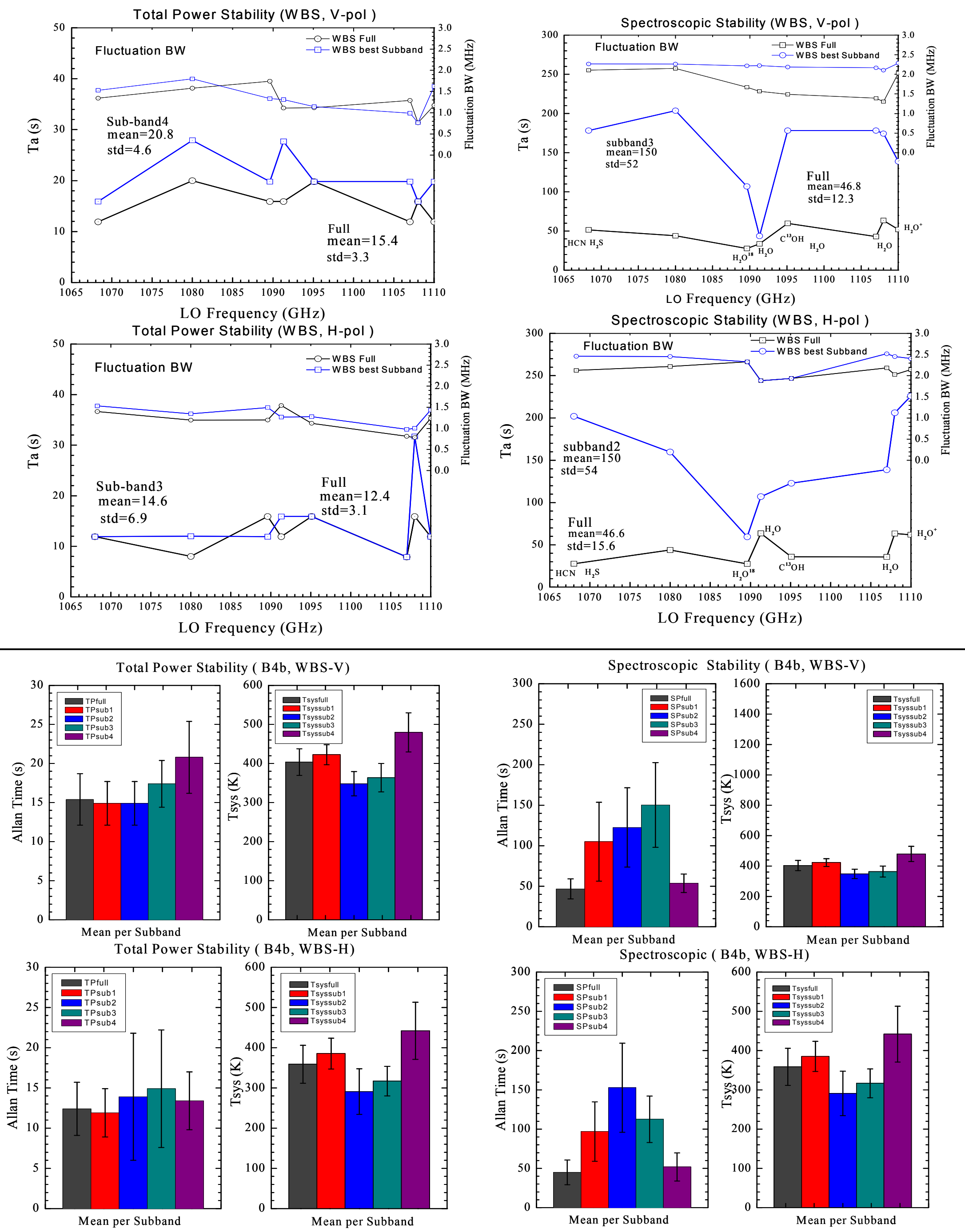


Fig. 61 Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 2, 3 are clearly the best.

5.7.8.2 HRS B4b

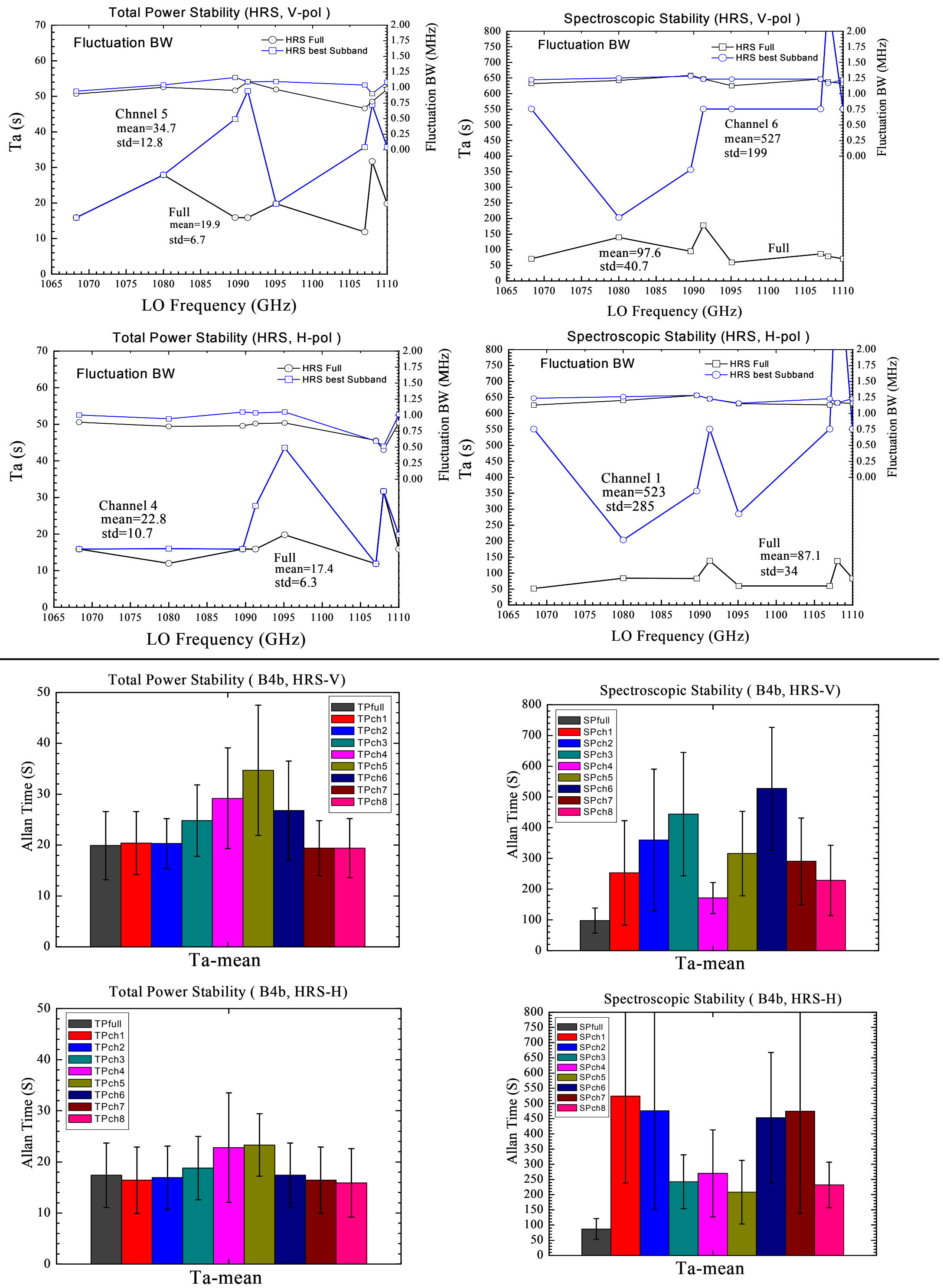


Fig. 62. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full

5.7.8.3 HRSfast B4b

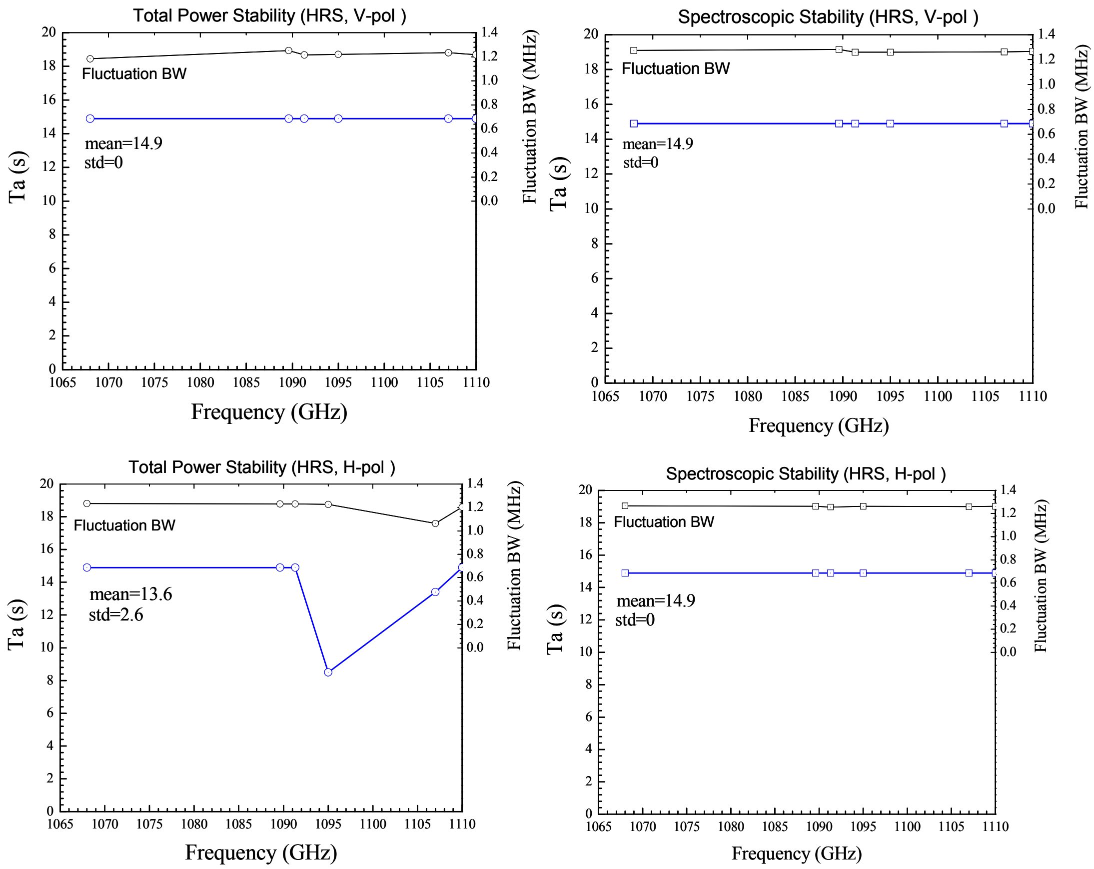


Fig. 63. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.8.4 Tsys B4b

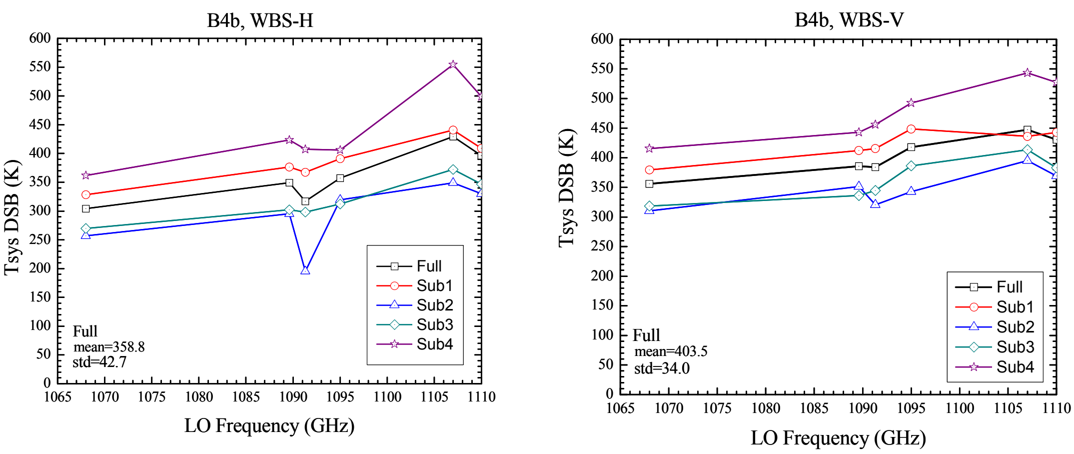


Fig. 64. System noise tmperature per polarization. B4 is a diplexer band.

5.7.9 B5a (beamsplitter band)

5.7.9.1 WBS B5a

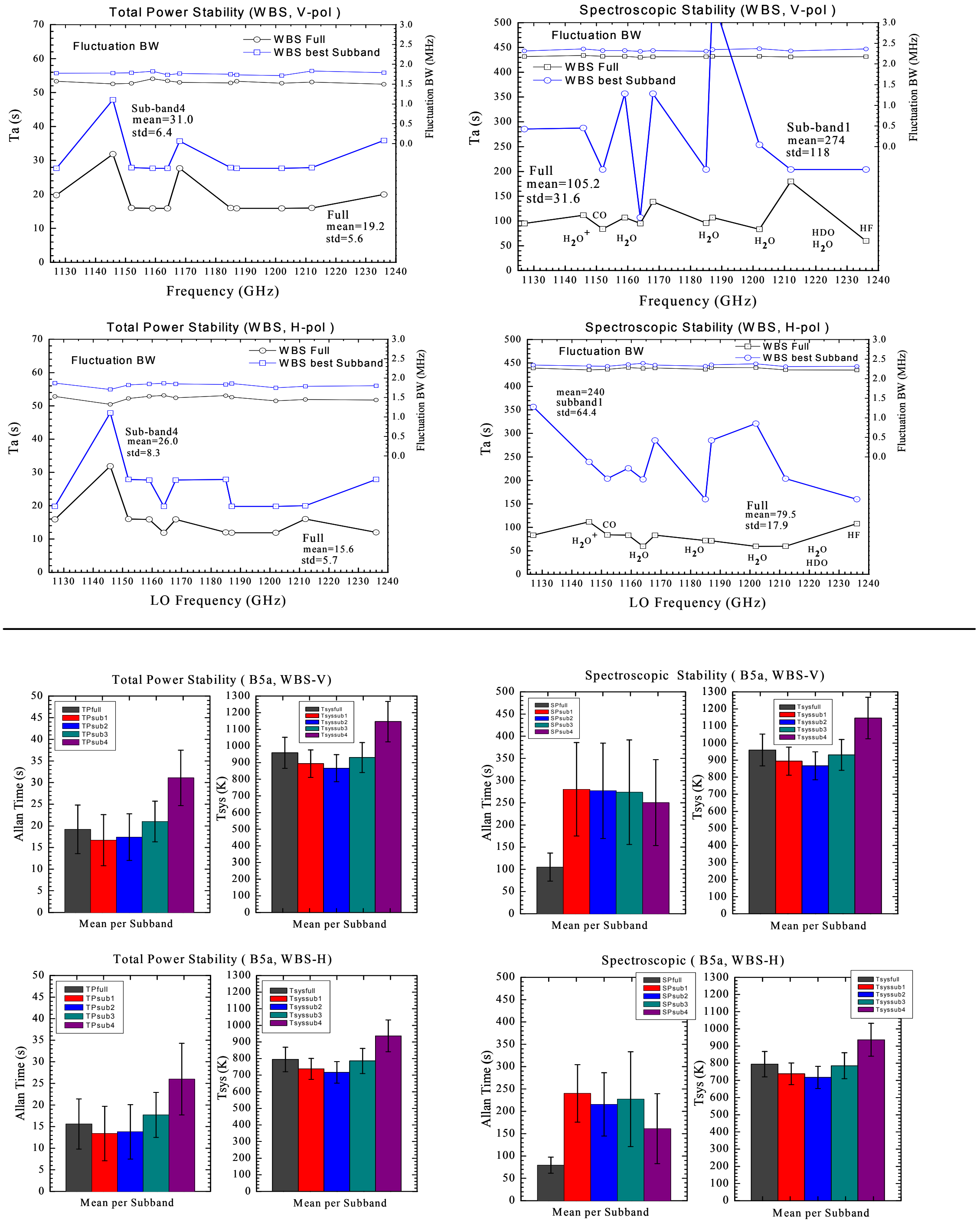


Fig. 65. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band.

5.7.9.2 HRS B5a

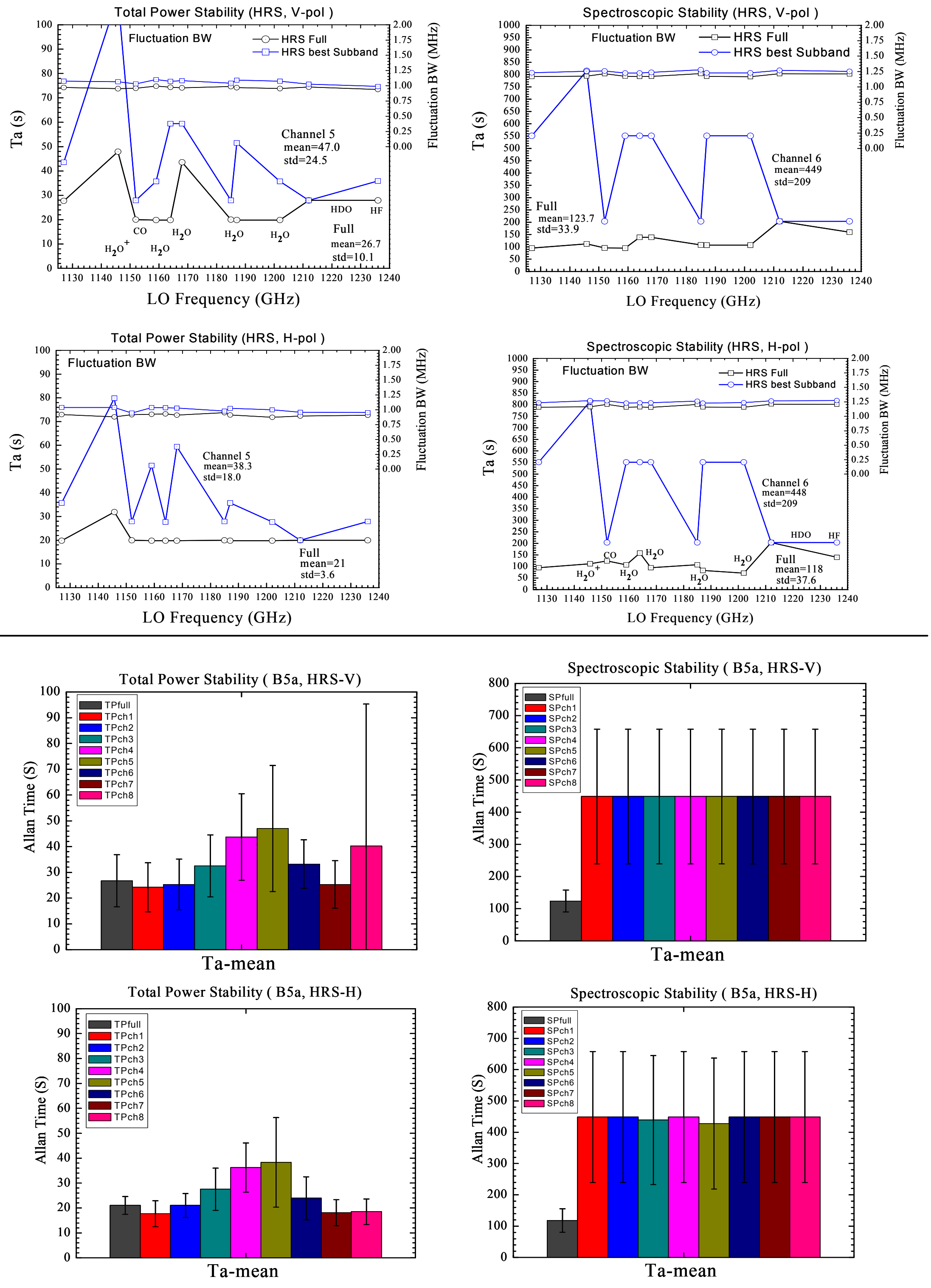


Fig. 66. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.9.3 HRSfast B5a

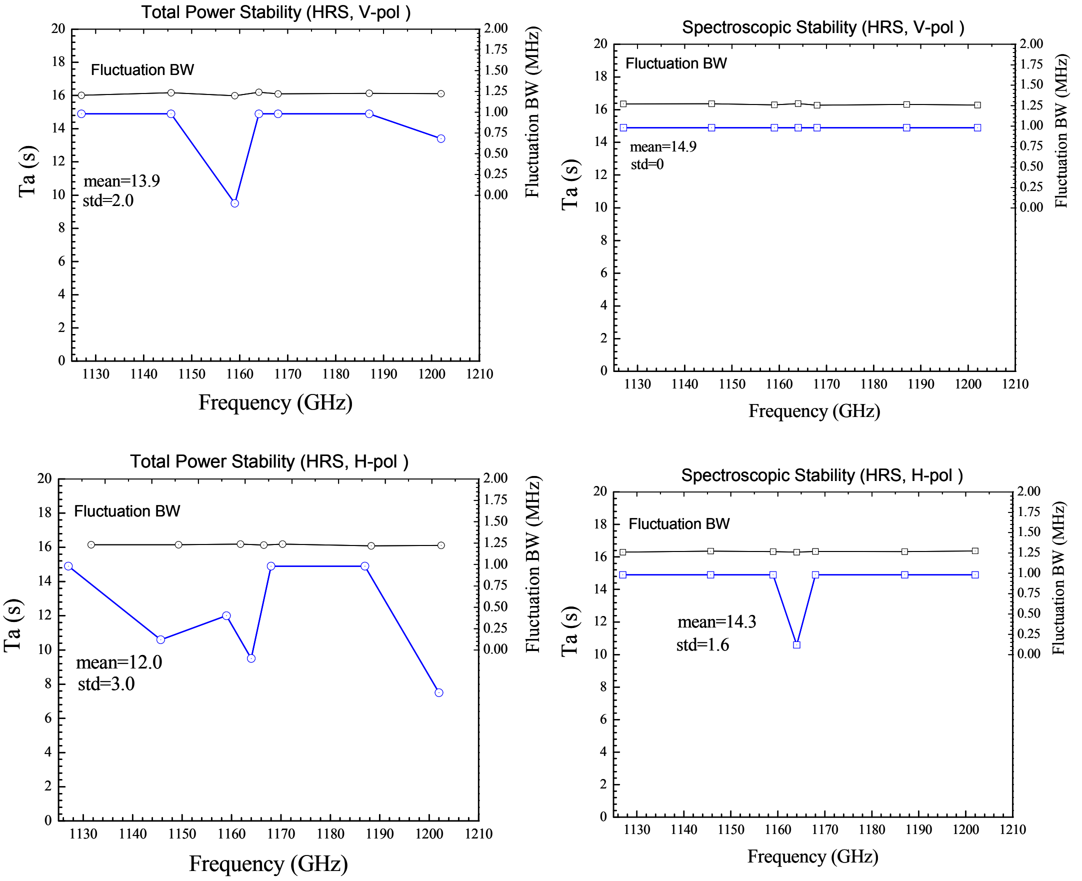


Fig. 67. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.9.4 Tsys B5a

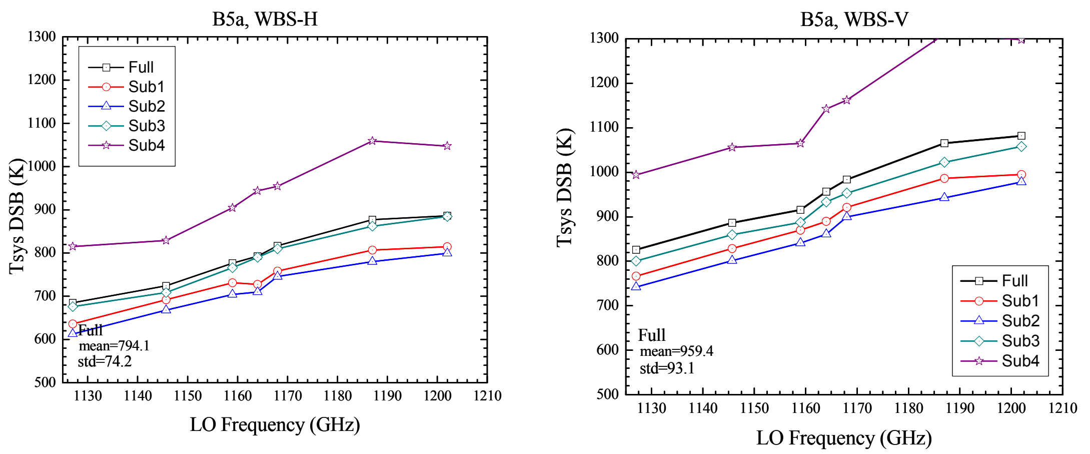


Fig 68. System noise temperature per polarization. B5 is a beamsplitter band. WBS Sub-bands 1-3 are clearly the most sensitive. There is no effect on the stability.

5.7.10 B5b (beamsplitter band)

5.7.10.1 WBS B5b

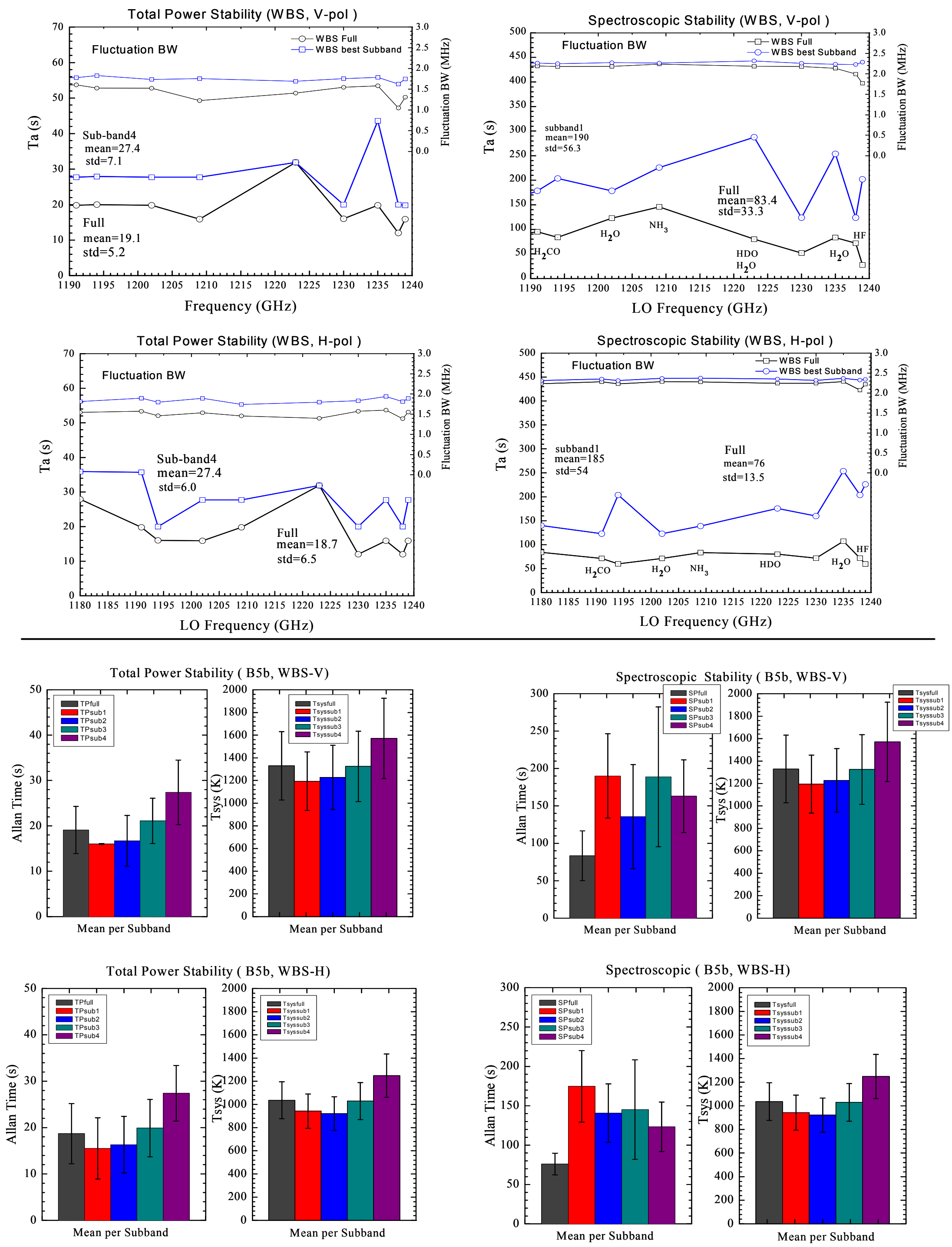


Fig. 69 Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band.

5.7.10.2 HRS B5b

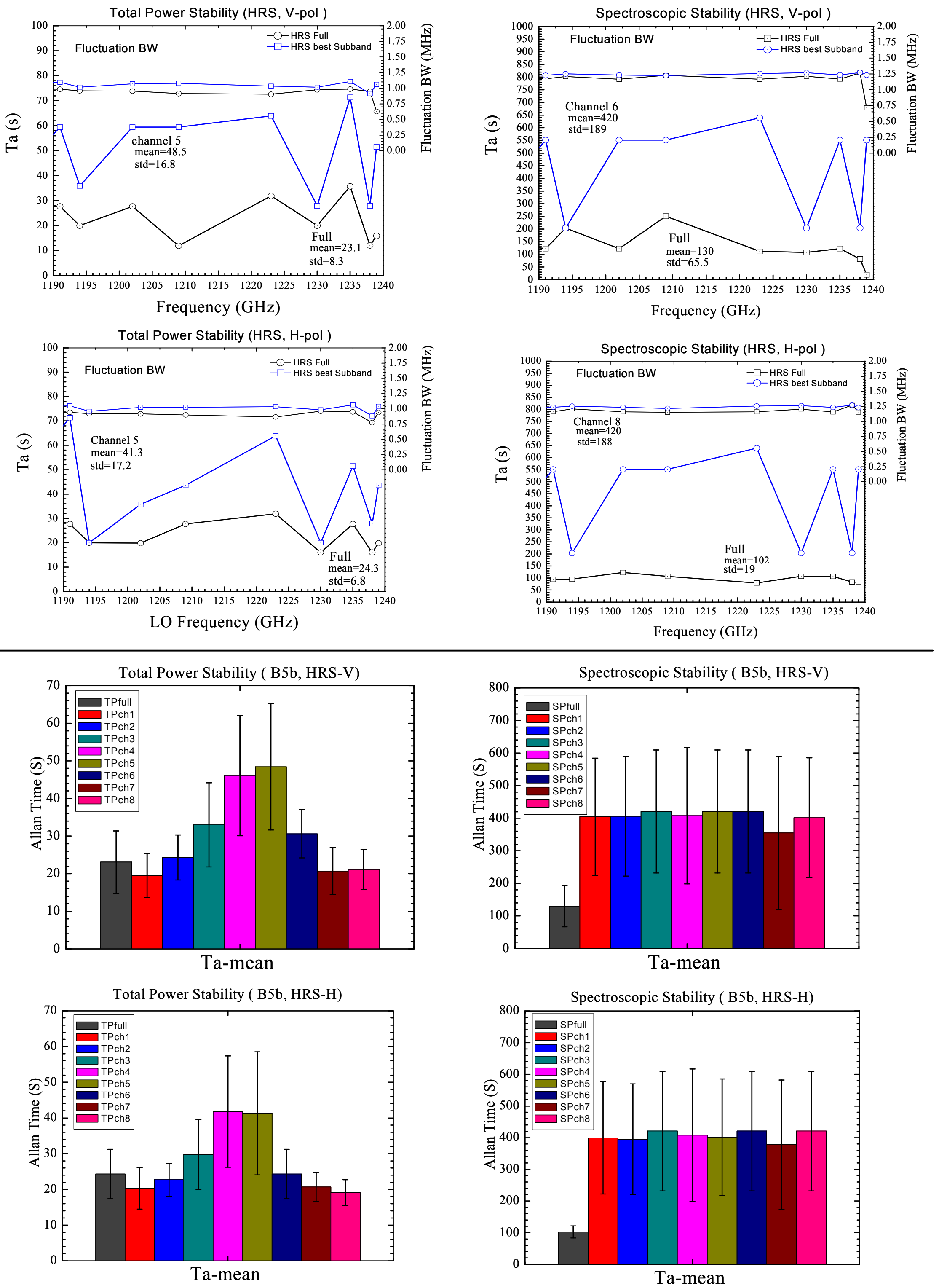


Fig. 70. Top: HRS Total Power and spectroscopic stability vs. frequency. Bottom: Stability distribution per sub-band. Note the difference in spectroscopic stability per HRS channel vs. Full.

5.7.10.3 HRSfast B5b

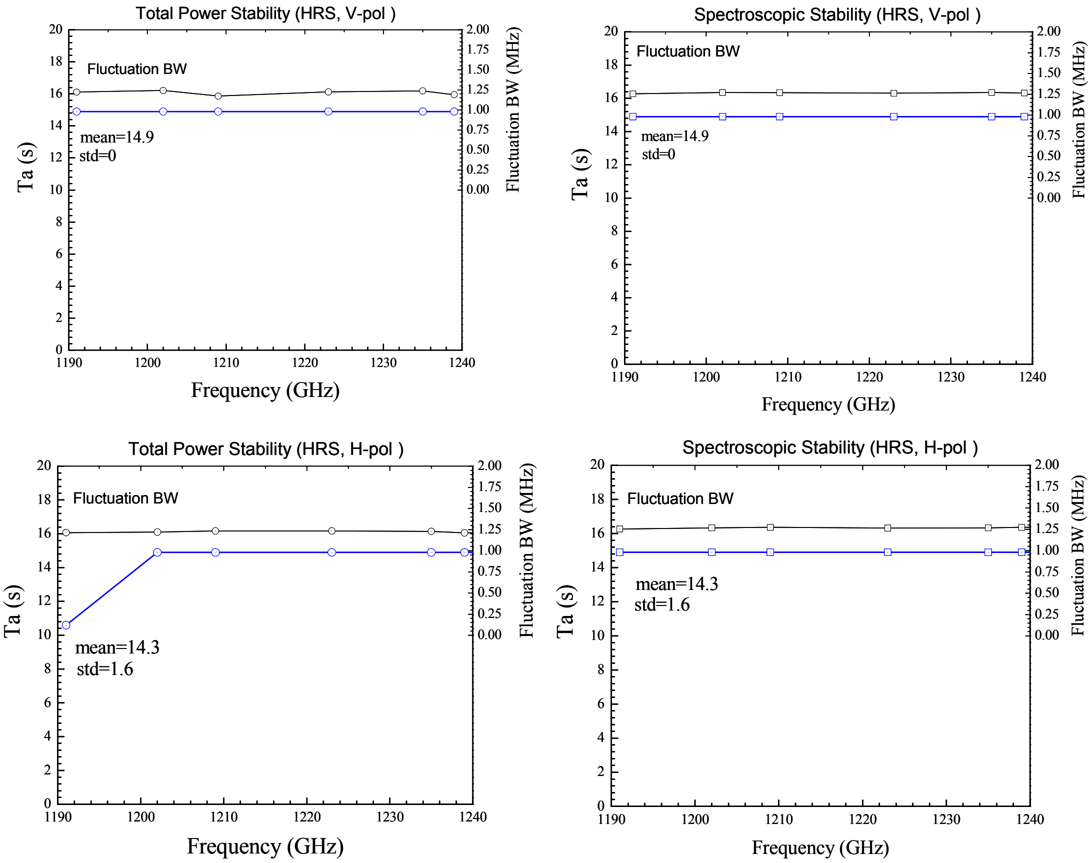


Fig. 71. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.10.4 Tsys B5b

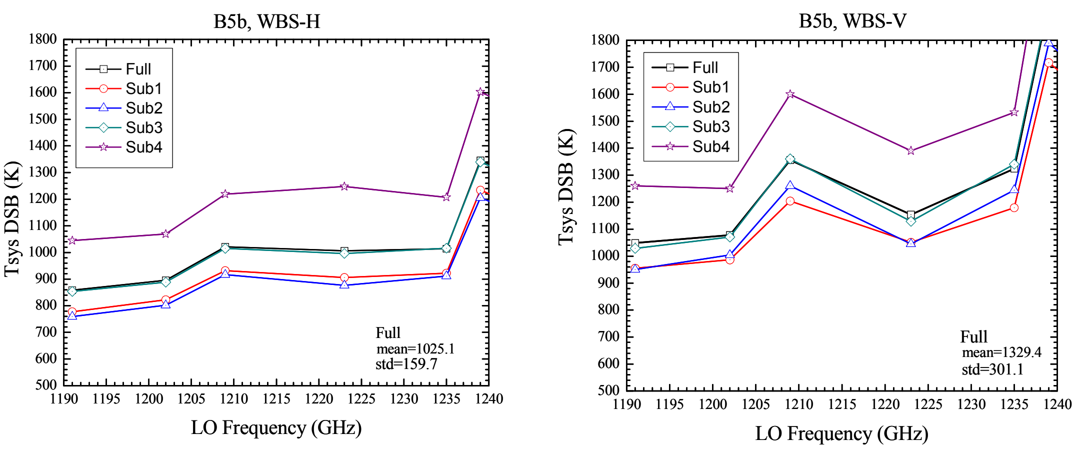


Fig. 72. System noise temperature per polarization. B5 is a beamsplitter band. WBS Sub-bands 1-3 are clearly the most sensitive. There is no effect on the stability.

5.7.11 B 6a (diplexer HEB band)

5.7.11.1 WBS B6a

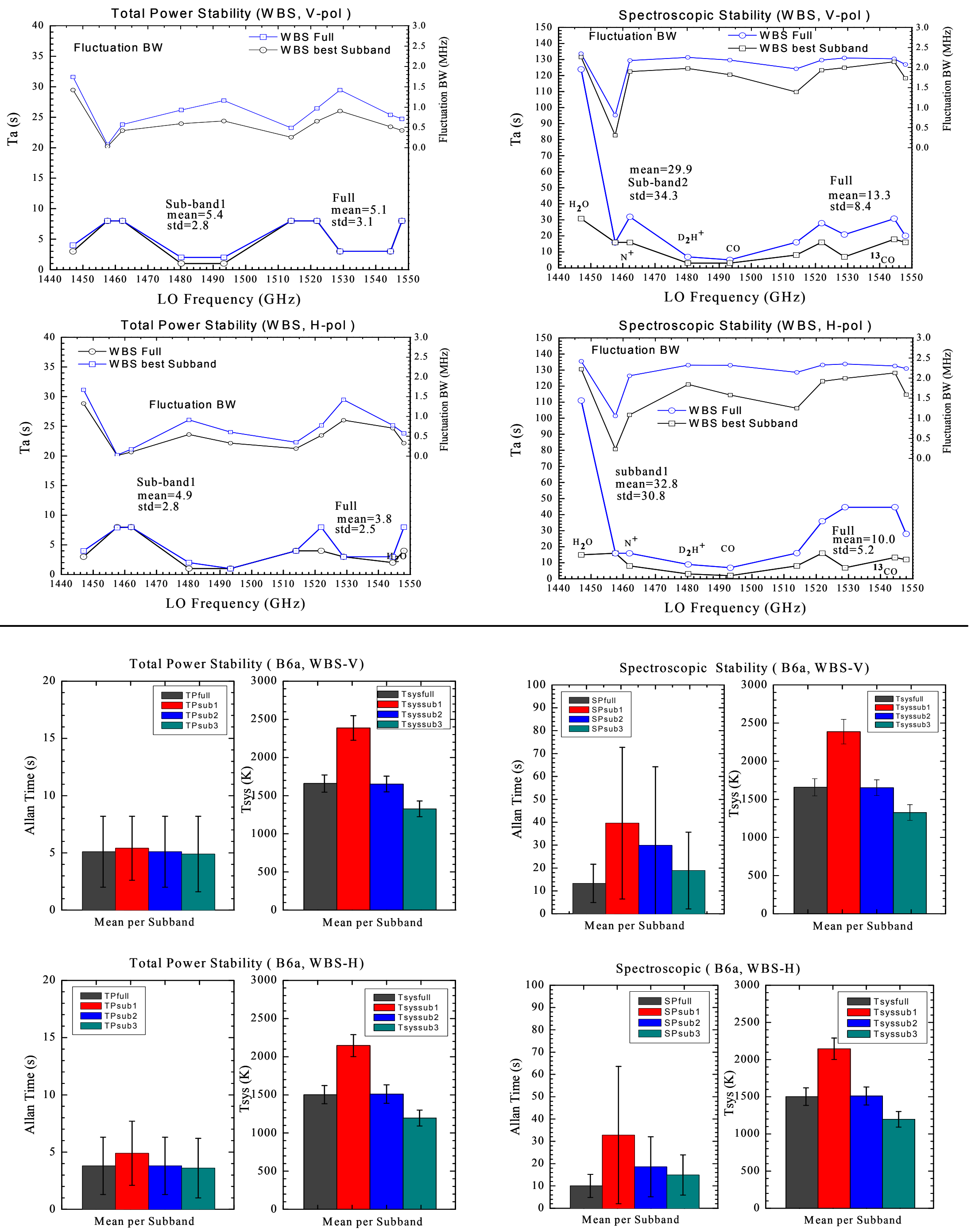


Fig. 73. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 1 (3.8-4.8 GHz) is clearly the least sensitive and therefore most stable.

5.7.11.2 HRSfast B6a

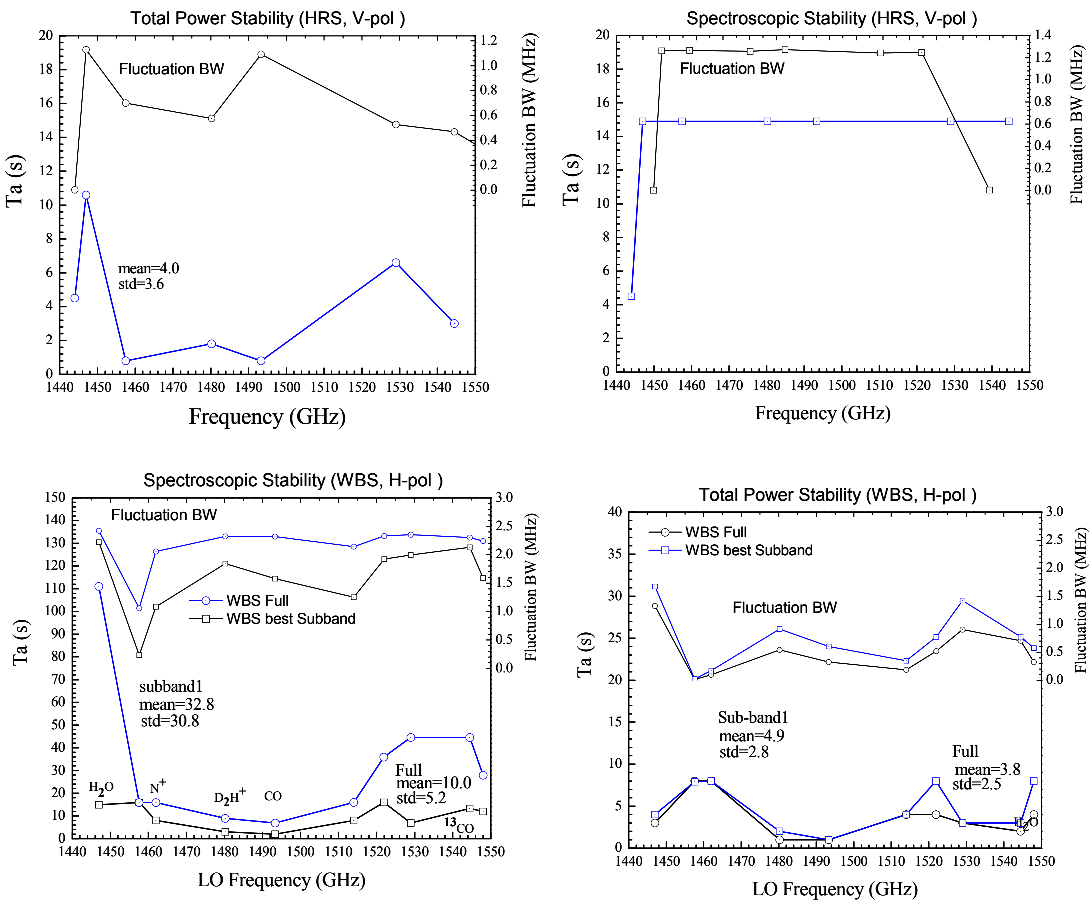


Fig. 74. Single HRS channel (1 GHz), fast readout at 6 Hz.

5.7.11.3 Tsys B6a

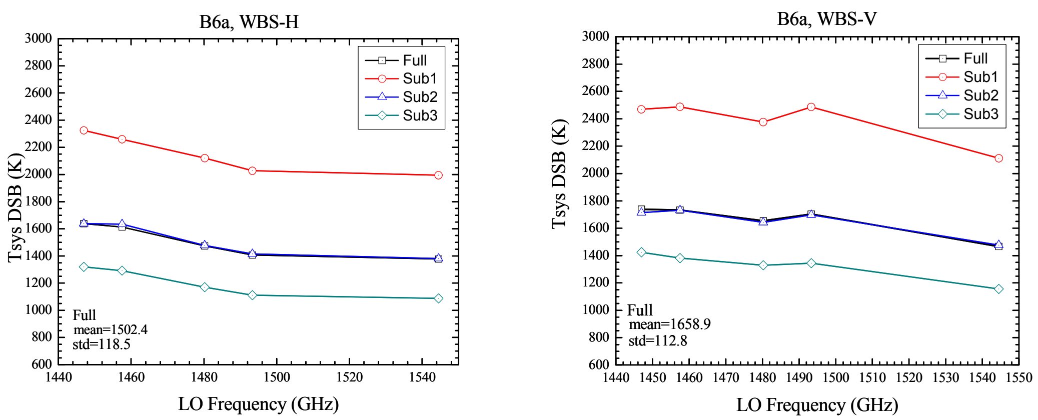


Fig. 75. System noise temperature per polarization. B6 is an HEB and diplexer band. Do I need to say more... Sub-band3 is most sensitive, but also most unstable. This may change in flight.

5.7.12 B6b (diplexer HEB band)

5.7.12.1 WBS B6b

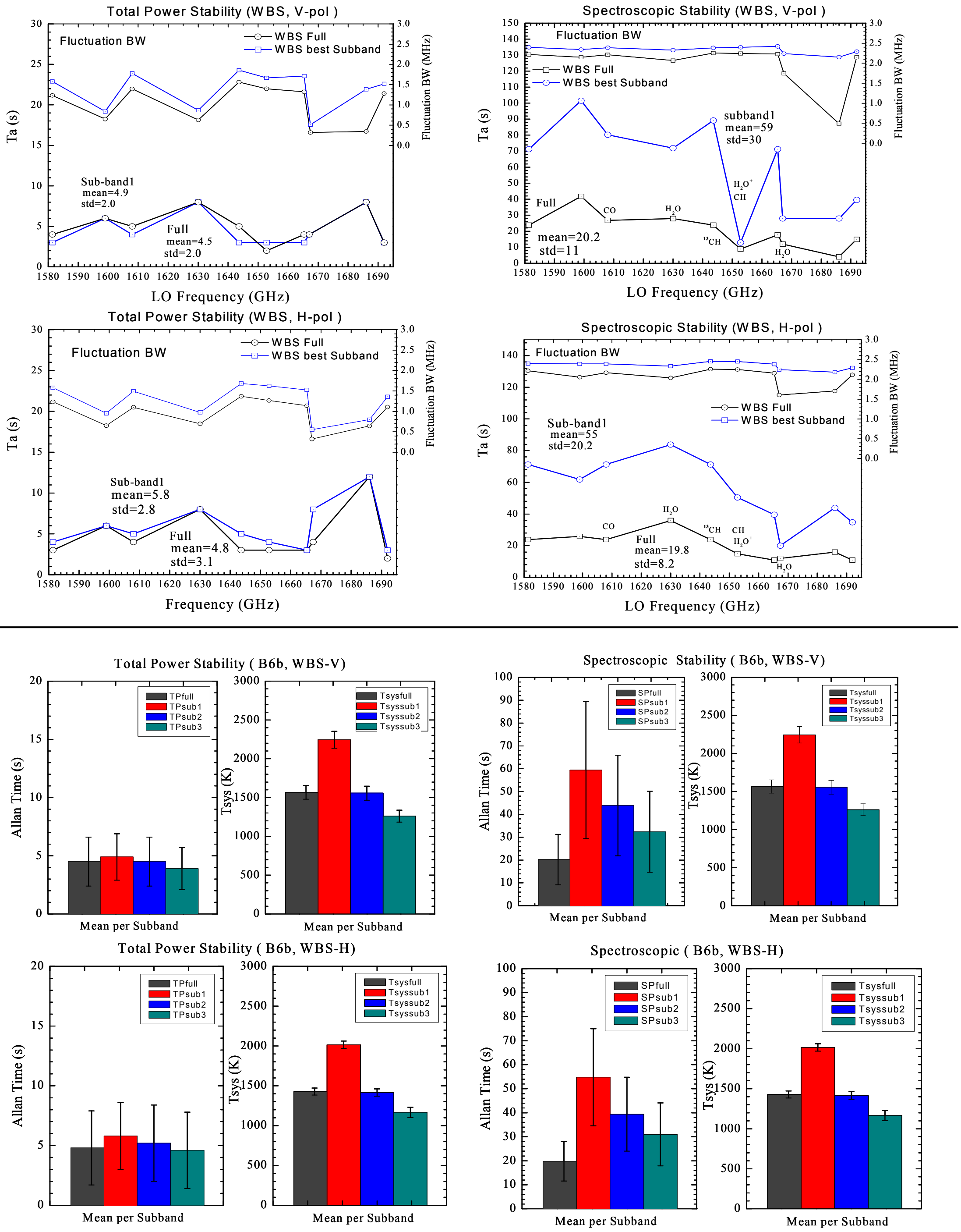


Fig. 76. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 1 (3.8-4.8 GHz) is clearly the least sensitive and therefore most stable.

5.7.12.2 HRSfast B6b

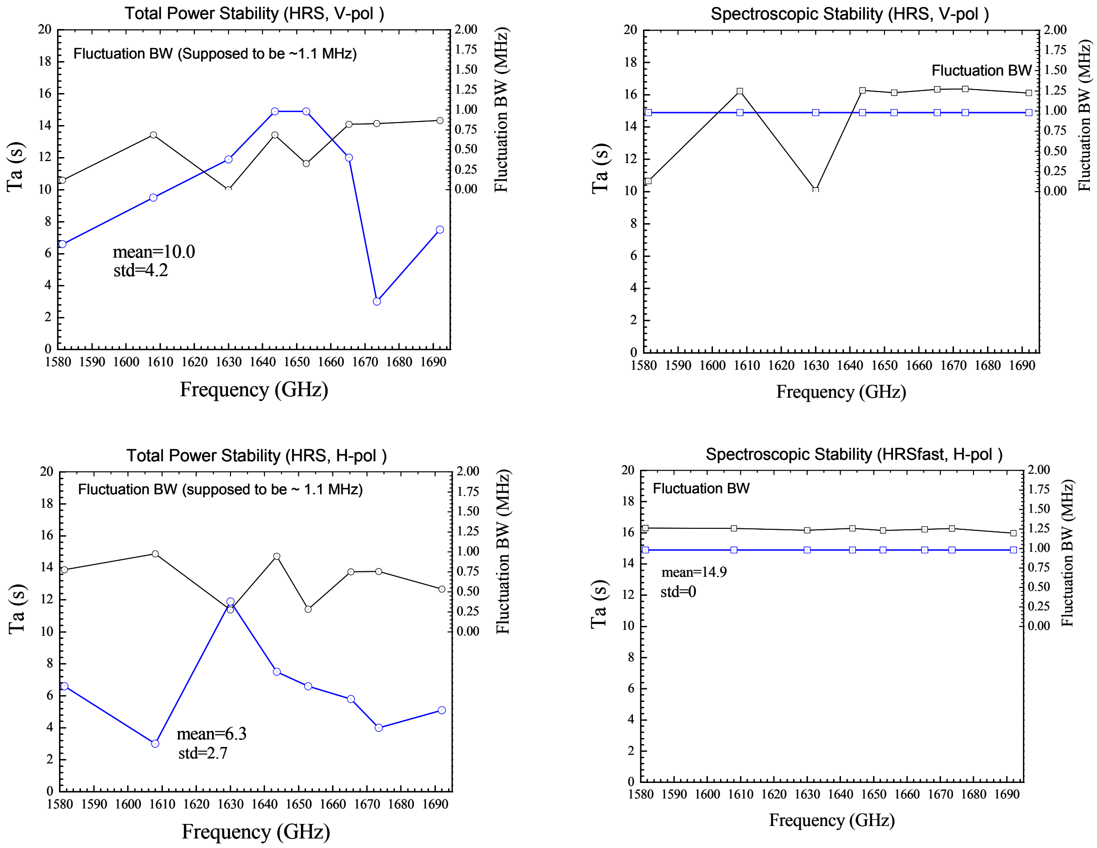


Fig 77. Single HRS channel (1 GHz), fast readout at 6 Hz.

5.7.12.3 Tsys B6b

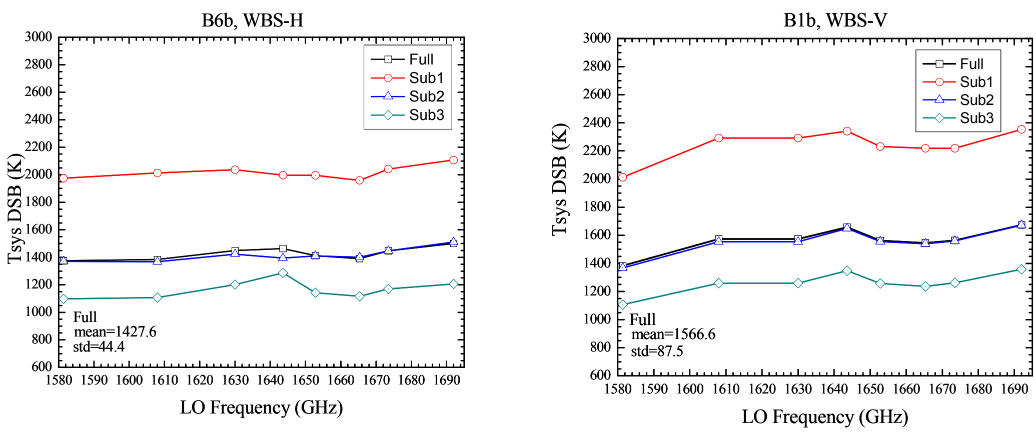


Fig. 78. System noise temperature per polarization. B6 is an HEB and diplexer band. Sub-band3 is most sensitive, but also most unstable. This may change in flight.

5.7.13 B7a (diplexer HEB band)

5.7.13.1 WBS B7a

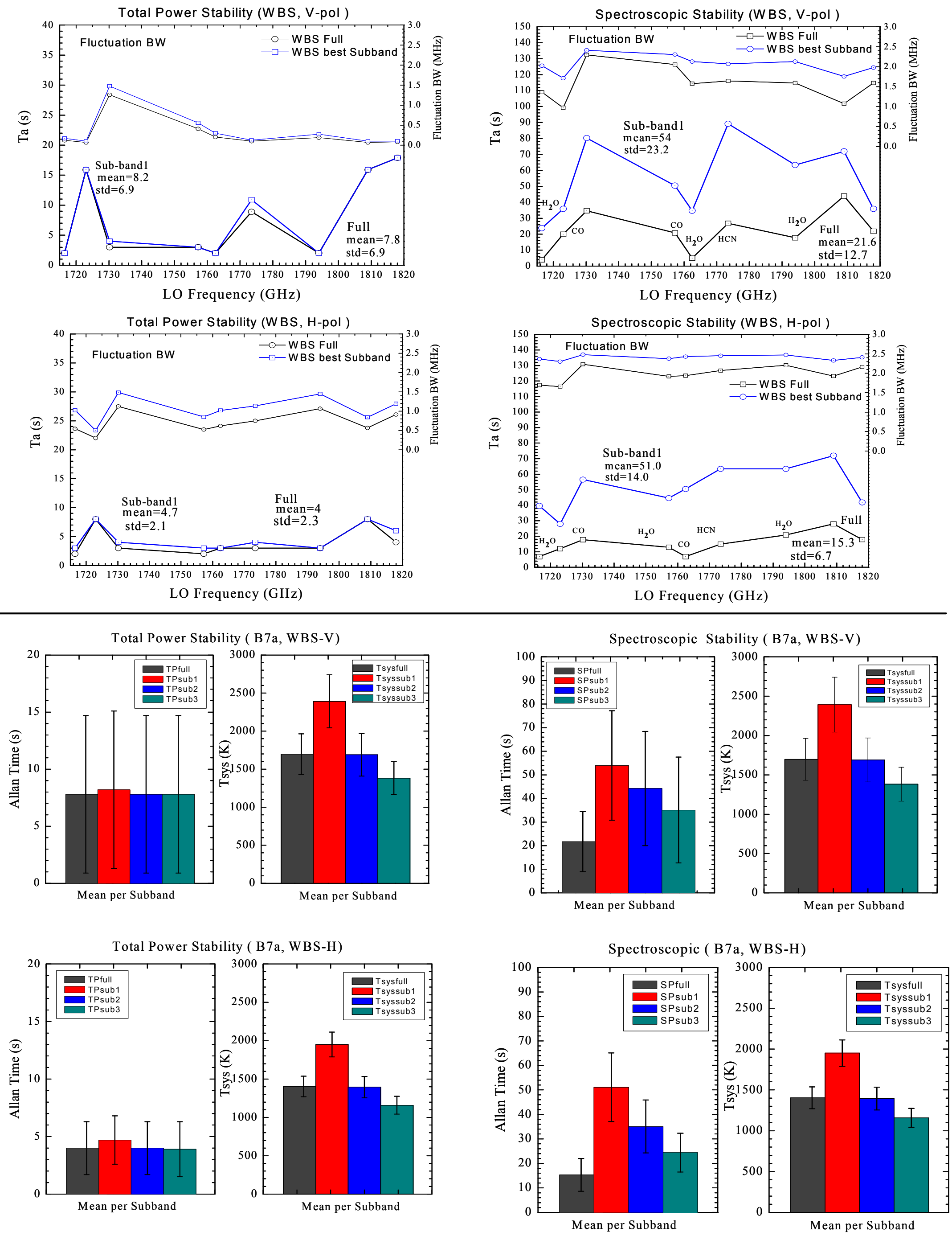


Fig. 79. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band. In regard to spectroscopic system stability, sub-band 1 (3.8-4.8 GHz) is clearly the least sensitive and therefore most stable.

5.7.13.2 HRSfast B7a

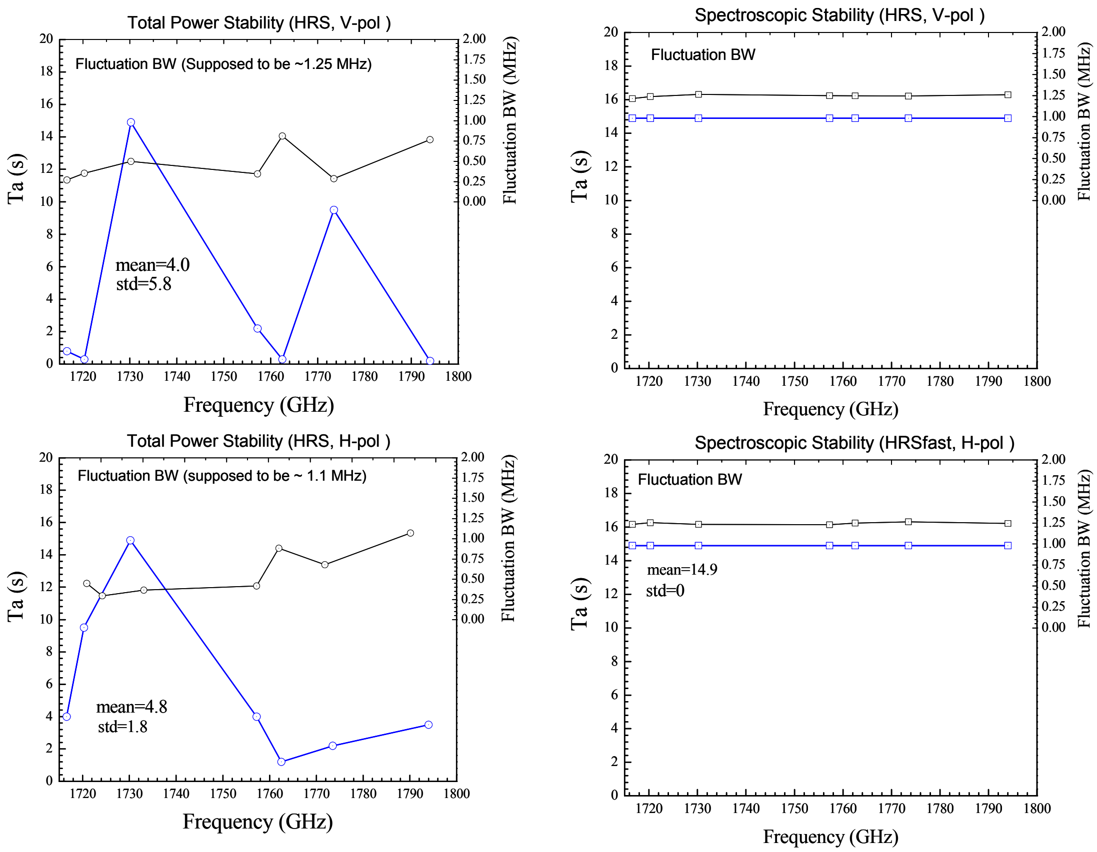


Fig. 80. Single HRS channel (1 GHz) , fast readout at 6 Hz.

5.7.13.3 Tsys B7a

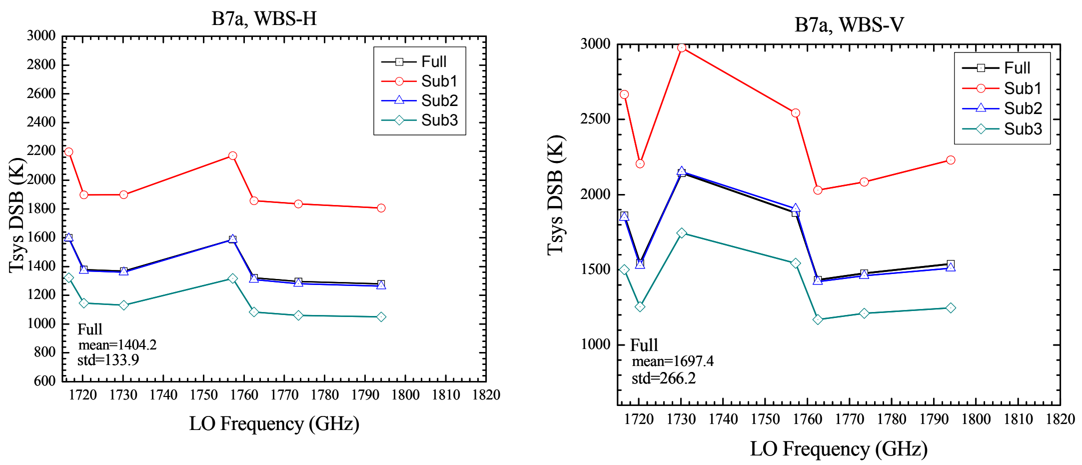


Fig. 81. System Temperature per polarization. B7 is an HEB and diplexer band. Sub-band3 is most sensitive, but also most unstable. This may change in flight.

5.7.14 B7b (diplexer HEB band)

5.7.14.1 WBS B7b

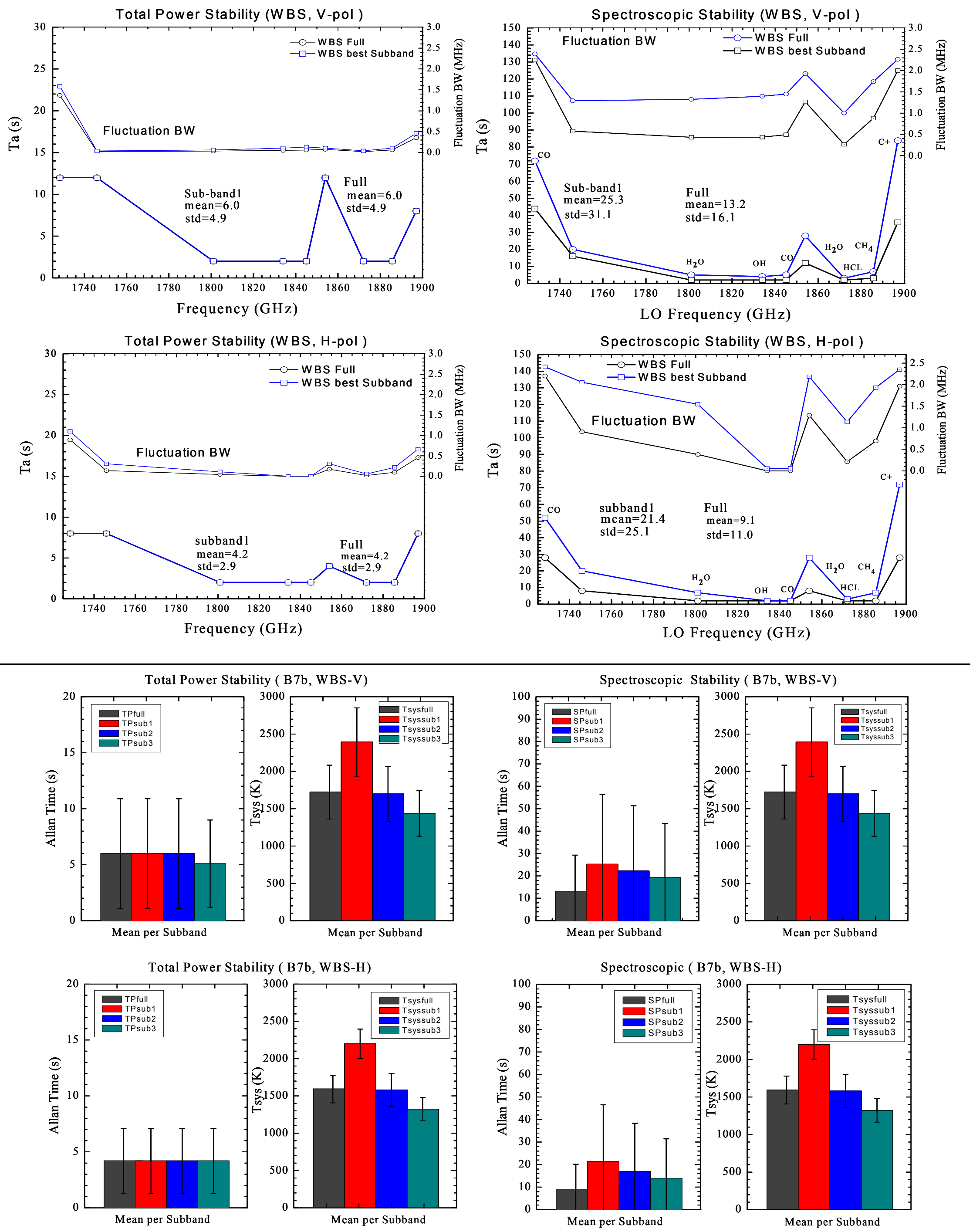


Fig. 82. Top: WBS Total Power and spectroscopic stability vs. frequency. Bottom: Stability and Tsys distribution per sub-band In regard to spectroscopic system stability, sub-band 1 (3.8-4.8 GHz) is clearly the least sensitive and therefore most stable.

5.7.14.2 HRSfast B7b

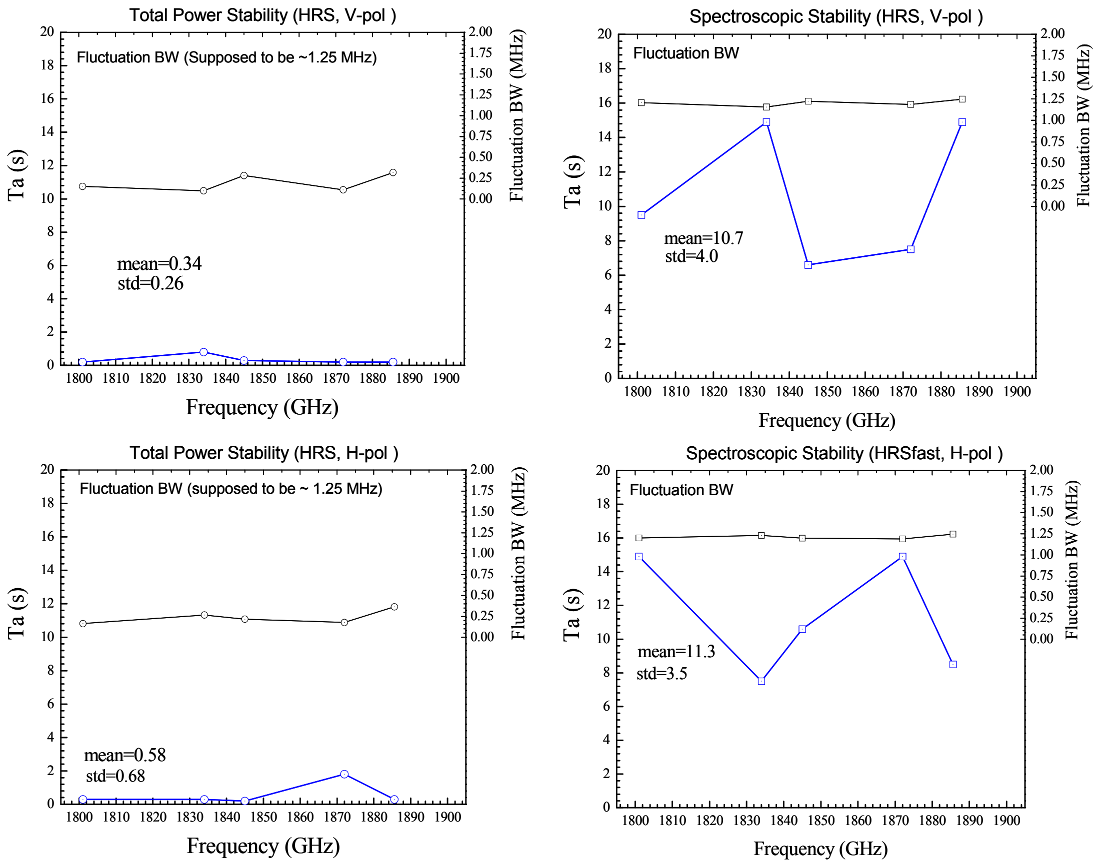


Fig. 83. Single HRS channel (1 GHz), fast readout at 6 Hz. B7b has some serious issues as measured during the LT –FM phase.

5.7.14.3 Tsys B7b

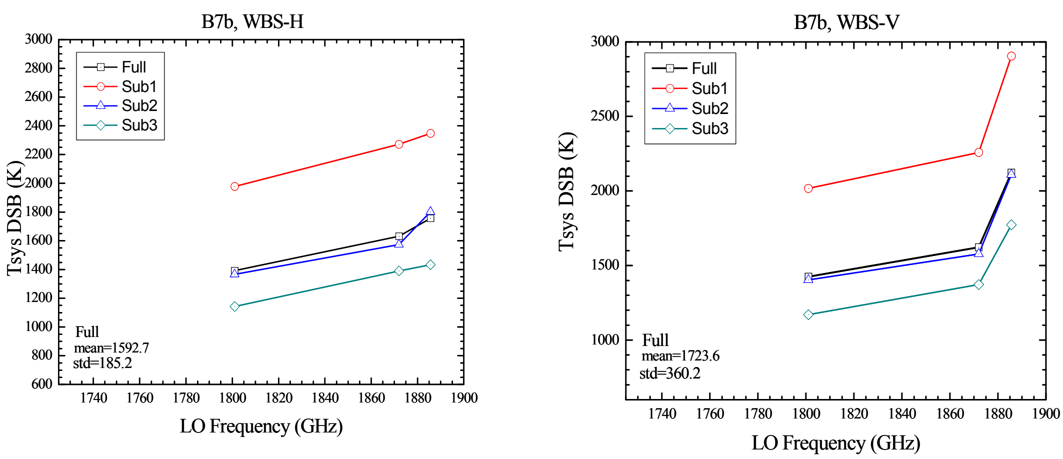


Fig. 84. System noise temperature per polarization. B7 is an HEB and diplexer band. It clearly has some issues. TV/PV stability measurements will be very important, as for all HEB bands.

5.8 System and Differential Stability Tabulated, all bands (WBS)

WBS-V

		Continuum [1-4] Stability (mean/std)		Spectroscopic [1-4] Stability (mean/std)		Diff. Load-Chop [1-4] Spectroscopic		Diff. Internal-Load [1-4] Spectroscopic		Diff. Load-Switch (DBS) [1-4] Spectroscopic		Tsys SSB (K)	RMS (mK) in 600s
band	Freq. (GHz)	spec > 5s		spec > 75s		spec > 600s		spec > 600s		spec > 600s			
		Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Mean	Mode=Diff
B1a	488-522	22.4/9.7	35.0/14.2	89.0/41.4	303.9/102.4	> 1800	> 1800	359.4	>=650	>> 2250	>> 2250	144.2	8.3
B1b	566-628	25.7/12.9	29.7/16.5	87.9/51.1	223.4/84.2	> 1800	> 1800	279.5	>=650	>> 2250	>> 2250	166.8	9.6
B2a	642-710	17.7/118	23.9/118	94.5/268	324.0/129.8	> 1800	> 1800	>=700	>=850	>> 2250	>> 2250	275.8	15.9
B2b	724-793	12.7/6.7	15.2/7.4	86.1/41.2	246.1/91.9	> 1800	> 1800	558.9	718.6	>> 2250	>> 2250	325.2	18.8
B3a	807-852	6.4/3.8	6.8/3.8	21.5/11.4	99.8/53.2	>> 900	>> 900	103.7	574.2	> 1800	> 1800	631.6	36.5
B3b	866-953	13.1/7.5	13.9/8.0	56.1/27.4	192.6/85.0	>> 900	>> 900	>=650	>=850	> 1800	> 1800	538.6	31.1
B4a	980-1040	9.0/4.5	10.6/7.0	37.7/24.9	178.4/109.2	>> 900	>> 900	451.8	>=850	>> 2250	>> 2250	805.4	46.5
B4b	1065-1115	15.4/3.3	20.8/4.6	46.8/12.3	150.3/52.3	>> 900	>> 900	800.6	>=850	> 2250	> 2250	807	46.6
B5a	1127-1178	19.2/5.6	31.1/6.4	105.2/31.6	280.3/105.3	>> 900	>> 900	>=850	>=850	> 1800	> 1800	1918.8	110.8
B5b	1192-1242	19.1/5.2	27.4/7.1	83.4/33.3	190.1/56.4	>> 900	>> 900	>=850	>=850	> 1800	> 1800	2658.8	153.5
B6a	1430-1570	5.1/3.1	5.4/2.8	13.3/8.4	39.6/33.1	>> 900	>> 900	700	>=800	> 1800	> 1800	3317.8	191.6
B6b	1580-1690	4.5/2.1	4.9/2.0	20.2/11.0	59.4/30.0	>> 900	>> 900	642	>=800	> 1800	> 1800	3133.2	180.9
B7a	1692-1845	7.8/6.9	8.2/6.9	21.7/12.7	54.0/23.2	>> 900	>> 900	700	>=800	> 1800	> 1800	3394.8	196.0
B7b	1719-1908	6.0/4.9	6.0/4.9	13.2/16.1	25.3/31.1	>> 900	>> 900	700	>=800	> 1800	> 1800	3705.8	214.0

WBS-H

		Continuum [1-4] Stability (mean/std)		Spectroscopic [1-4] Stability (mean/std)		Diff. Load-Chop [1-4] Spectroscopic		Diff. Internal-Load [1-4] Spectroscopic		Diff. Load-Switch (DBS) [1-4] Spectroscopic		Tsys SSB (K)	RMS (mK) in 600s
band	Freq. (GHz)	spec > 5s		spec > 75s		spec > 600s		spec > 600s		spec > 600s			
		Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Full	Best SubBand	Mean	Mode=Diff
B1a	488-522	17.2/5.0	27.6/11.3	72.8/17.1	210.9/94.9	> 1800	> 1800	575	>=650	>> 2250	>> 2250	150	8.7
B1b	566-628	17.0/7.8	21.0/7.2	65.8/24.9	161.6/70.9	> 1800	> 1800	279.5	>=650	>> 2250	>> 2250	180	10.4
B2a	642-710	17.7/45	26.9/7.1	68.4/14.1	286.8/129.6	> 1800	> 1800	717.7	>=850	>> 2250	>> 2250	246	14.2
B2b	724-793	12.0/5.8	16.2/8.3	77.8/21.7	243.7/123.4	> 1800	> 1800	718.6	814.4	>> 2250	>> 2250	398	23.0
B3a	807-852	9.1/3.8	9.6/4.7	33.8/19.7	93.4/71.8	>> 900	>> 900	250	300	> 1800	> 1800	209.7	12.1
B3b	866-953	9.9/3.4	11.5/4.0	68.8/39.8	130.6/67.2	>> 900	>> 900	>=650	>=850	> 1800	> 1800	934.2	53.9
B4a	980-1040	8.0/3.8	10.6/4.9	25.1/17.0	129.3/79.6	>> 900	>> 900	190.2	>=850	>> 2250	>> 2250	706	40.8
B4b	1065-1115	12.4/3.3	14.9/7.3	45.0/15.8	152.7/56.8	>> 900	>> 900	850	>=850	1870	> 2250	717.6	41.4
B5a	1127-1178	15.6/5.8	26.0/8.3	79.5/17.9	240.2/64.4	>> 900	>> 900	>=850	>=850	> 1800	> 1800	1588.2	91.7
B5b	1192-1242	18.7/6.5	27.4/6.0	76.0/13.7	174.6/45.5	>> 900	>> 900	>=850	>=850	> 1800	> 1800	2070.2	119.5
B6a	1430-1570	3.8/2.5	4.9/2.8	10.0/5.2	32.8/30.8	>> 900	>> 900	604.5	>=800	> 1800	> 1800	3004.8	173.5
B6b	1580-1690	4.8/3.1	5.8/2.8	19.8/8.2	54.8/20.2	>> 900	>> 900	700	>=800	> 1800	> 1800	2855.2	164.8
B7a	1692-1845	4.0/2.3	4.7/2.1	15.3/6.7	51.1/14.0	>> 900	>> 900	700	>=800	> 1800	> 1800	2808.4	162.1
B7b	1719-1908	4.2/2.9	4.2/2.9	9.1/11.0	21.4/25.1	>> 900	>> 900	700	>=800	> 1800	> 1800	3185.4	183.9

Legend:

(red)	Out of spec
(orange)	Marginal
(green)	In spec
(pale yellow)	No data

[1] WBS noise fluctuation bandwidth ~2MHz
[2] Full WBS: 8000 channels (4 GHz)
[3] WBS Subband: 2000 channels (1 GHz)
[4] Ta at 50% from the Radiometer Eqn

Table 4. WBS Measured system and differential Mean/Standard Deviation. Yellow is marginal, red is very poor. Note that in the HEB bands (B6, B7) the system stability is very poor, however differential stability is quite alright (see next section: Differential Stability). It is important to re-measured these results in the TV and PV phase.

5.9 System and Differential Stability Tabulated, all bands (HRS)

HRS-V

		Continuum [1-4] Stability (mean/std)		Spectroscopic [1-4] Stability (mean/std)		Diff. Load-Chop [1-4] Spectroscopic		Diff. Internal-Load [1-4] Spectroscopic		Diff. Load-Switch (DBS) [1-4] Spectroscopic		Tsys SSB (K)	RMS (mK) in 600s
band	Freq. (GHz)	spec >7s		spec >100s		spec >850s		spec >850s		spec >850s			
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B1a	488-522	34.1/12. 0	49.1/17. 0	144.6/30. 0	598.4/332. 0	> 1800	> 1800	407.3	>=850	>> 2250	>> 2250	144.2	10.7
B1b	566-628	31.5/13. 8	43.8/12. 6	127.0/47. 7	709.9/575. 4	> 1800	> 1800	455.2	>=850	>> 2250	>> 2250	166.8	12.4
B2a	642-710	22.1/10. 9	35.3/21. 6	133.5/41. 6	473.6/201. 8	> 1800	> 1800	>=850	>=850	>> 2250	>> 2250	275.8	20.6
B2b	724-793	15.9/7. 4	22.2/10. 3	92.8/36. 6	459.3/191. 7	> 1800	> 1800	>= 700	>= 700	>> 2250	>> 2250	325.2	24.2
B3a	807-852	7.6/4. 0	8.4/4. 8	47.7/20. 4	404.3/189. 4	>> 900	>> 900	215.3	>= 700	> 1800	> 1800	631.6	47.1
B3b	866-953	13.1/7. 5	13.9/8. 0	56.1/27. 4	192.6/85. 0	>> 900	>> 900	>=850	>=850	> 1800	> 1800	538.6	40.1
B4a	980-1040	10.3/5. 7	81.4/231. 2	71.6/42. 7	435.4/234. 9	>> 900	>> 900	713.4	>=850	>> 2250	>> 2250	805.4	60.0
B4b	1065-1115	19.9/6. 7	34.7/12. 8	97.7/40. 7	527.3/199. 4	>> 900	>> 900	>= 700	>=850	>> 2250	>> 2250	807	60.2
B5a	1127-1178	26.7/10. 1	47.0/24. 5	123.7/33. 9	448.6/209. 0	>> 900	>> 900	>=850	>=850	> 1800	> 1800	1918.8	143.0
B5b	1192-1242	23.1/8. 3	48.4/16. 8	130.4/63. 5	420.8/188. 8	>> 900	>> 900	>=850	>=850	> 1800	> 1800	2658.8	198.2
B6a	1430-1570					>> 900	>> 900	800	>=850	> 1800	> 1800	3317.8	247.3
B6b	1580-1690					>> 900	>> 900	800	>=850	> 1800	> 1800	3133.2	233.5
B7a	1692-1845											3394.8	253.0
B7b	1719-1908											3705.8	276.2

HRS-H

		Continuum [1-4] Stability (mean/std)		Spectroscopic [1-4] Stability (mean/std)		Diff. Load-Chop [1-4] Spectroscopic		Diff. Internal-Load [1-4] Spectroscopic		Diff. Load-Switch (DBS) [1-4] Spectroscopic		Tsys SSB (K)	RMS (mK) in 600s
band	Freq. (GHz)	spec >7s		spec >100s		spec >850s		spec >850s		spec >850s			
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B1a	488-522	32.8/24. 2	60.8/53. 8	106.2/22. 0	598.4/332. 0	> 1800	> 1800	> =650	>=850	>> 2250	>> 2250	150	11.2
B1b	566-628	22.8/7. 4	43.8/21. 6	95.5/14. 8	746.2/570. 6	> 1800	> 1800	511.1	>=850	>> 2250	>> 2250	180	13.4
B2a	642-710	26.1/6. 3	44.1/14. 3	114.9/32. 5	473.6/201. 8	> 1800	> 1800	>=800	>=850	>> 2250	>> 2250	246	18.3
B2b	724-793	17.2/8. 0	26.1/14. 5	91.4/31. 7	472.5/183. 9	> 1800	> 1800	>= 700	>=850	>> 2250	>> 2250	398	29.7
B3a	807-852	11.1/5. 5	12.7/8. 6	58.1/38. 8	360.9/241. 1	>> 900	>> 900	215.3	358.8	> 1800	> 1800	209.7	15.6
B3b	866-953	13.1/6. 8	23.9/30. 4	72.7/29. 7	428.3/203. 3	>> 900	>> 900	>=850	>=850	> 1800	> 1800	934.2	69.6
B4a	980-1040	9.3/4. 9	17.2/10. 6	59.0/42. 7	403.4/248. 5	>> 900	>> 900	507.3	>=850	>> 2250	>> 2250	706	52.6
B4b	1065-1115	17.4/6. 3	23.3/6. 1	87.1/34. 0	523.8/285. 8	>> 900	>> 900	>= 700	>=850	1870	> 2250	717.6	53.5
B5a	1127-1178	21.0/3. 6	38.3/18. 0	117.9/37. 7	448.6/209. 0	>> 900	>> 900	>=850	>=850	> 1800	> 1800	1588.2	118.4
B5b	1192-1242	24.3/6. 9	41.8/15. 6	102.2/18. 9	420.8/188. 8	>> 900	>> 900	>=850	>=850	> 1800	> 1800	2070.2	154.3
B6a	1430-1570					>> 900	>> 900	507.3	>=850	> 1800	> 1800	3004.8	224.0
B6b	1580-1690					>> 900	>> 900	800	>=850	> 1800	> 1800	2855.2	212.8
B7a	1692-1845											2808.4	209.3
B7b	1719-1908											3185.4	237.4

Legend:

- Out of spec (red)
- Marginal (orange)
- In spec (green)
- No data (yellow)

[1] HRS noise flucuation bandwidth ~1.2MHz
[2] Full HRS: 8 256 MHz channels covering 4 GHz IF
[3] HRS Subband: 256 MHz
[4] Ta at 50% from the Radiometer Eqn

Table 5. HRS Measured system and differential Mean/Standard Deviation. Yellow is marginal, red is very poor. Note that in the HEB bands (B6, B7) the system stability is very poor, however differential stability is quite alright (Differential Stability see next section).

6 Differential Stability

6.1 Load-Chop Differential Stability

Objectives

Verify the differential stability between internal Cold and external Cold load (telescope) due to broadband gain variations, standing wave modulation, temperature drift…
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref]..
Provide input for the efficiency computation/loop-optimization AOT's.
Obtain Hot-Cold calibration loop parameter...
Search for plat forming effects, baseline offsets

Test Procedure

```
Configure instrument, nominal bias, B-field, diplexer etc, stabilize if necessary
for mixer_band = 1, 5 do begin  {
    select both WBS, HRS low resolution mode  (4 second readout)
    select focal plane chopper, slow chop mode
      for freq = flo1, flo2     {          (2 LO frequencies near the edge of the band)
        adjust IF level
         perform WBS cal using the internal calibration source (zero-comb, RD20)
            for i = 0, 450 do {                              (1 hour)
              for i2 = 0, 1 do {                             (loop 2x)
                select chopper internal Cold BB
                acquire WBS/HRS spectrum {2sec}
                select chopper external Cold BB
                acquire WBS/HRS spectrum {2sec}
              }
            }
      }
}
end
```

CUS script name:

- *Testmode_stability_loadchop (1hour/measurement)*

Note1: Total integration time 60 minutes * 2.
Note2: Symmetric chop: Pc, Pc', Pc', Pc…
Housekeeping data should be acquired and stored throughout this and other test procedures.

Result

The total power and spectroscopic system gain stability between internal CBB and external CBB as a function of integration time in load-chop mode for each mixer band.
Dependence of stability on the temperature (LO standing wave) environment.
Knowledge of plat forming spectrometers, systematic baseline offsets
Loop parameters AOT
Not included in the results are possible standing wave modulation in the telescope structure.

6.1.1 B1a 494.4 GHz Load-Chop

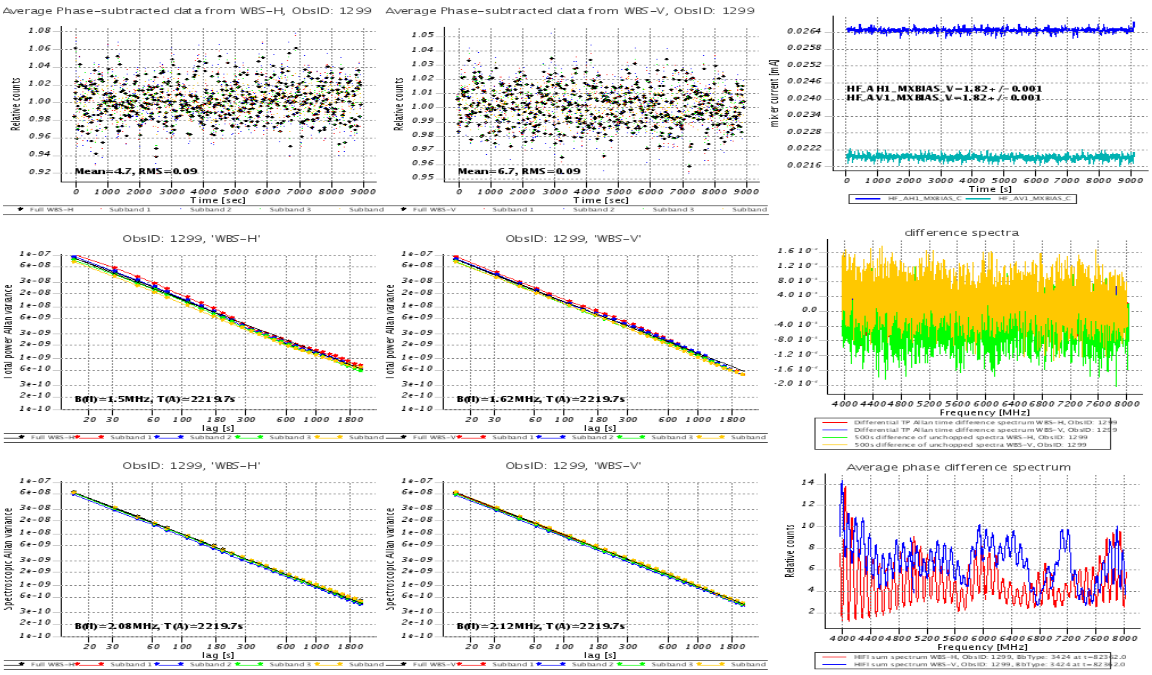


Fig. 85. B1a Load Chop differential stability for 9000s. Baseline quality looks good. Load-chop is w/o telescope optics.

6.1.2 B2a 640 GHz load-Chop

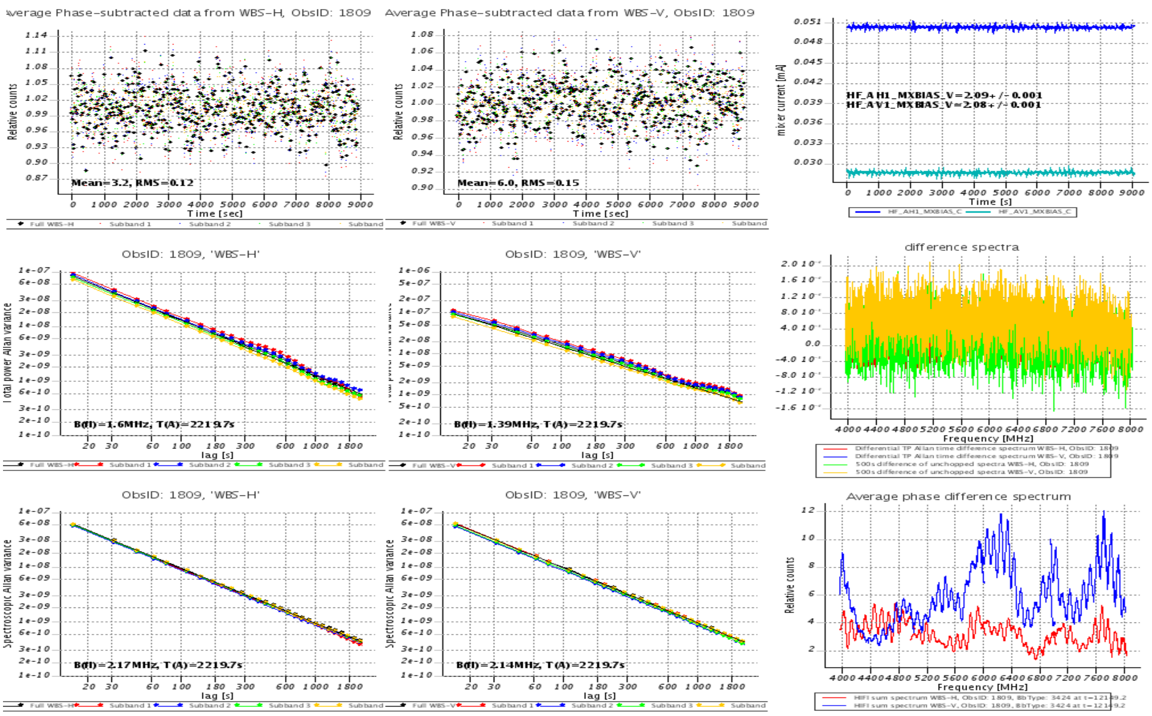


Fig. 86. B2a Load Chop differential stability for 9000s. Baseline quality looks good.

6.1.3 B2b 758 GHz Load-Chop

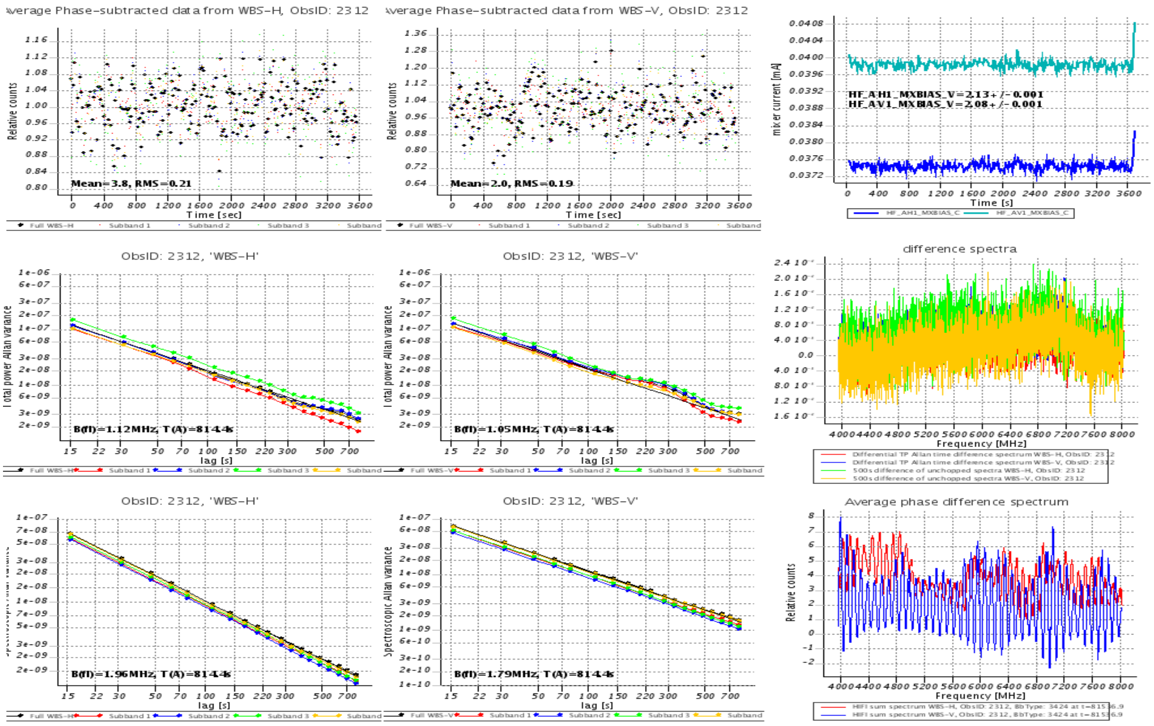


Fig. 87. B2b Load Chop differential stability for 3600s. Some baseline drift in WBS sub-band 4 after 500s.

6.1.4 B3a 841 GHz Load-Chop

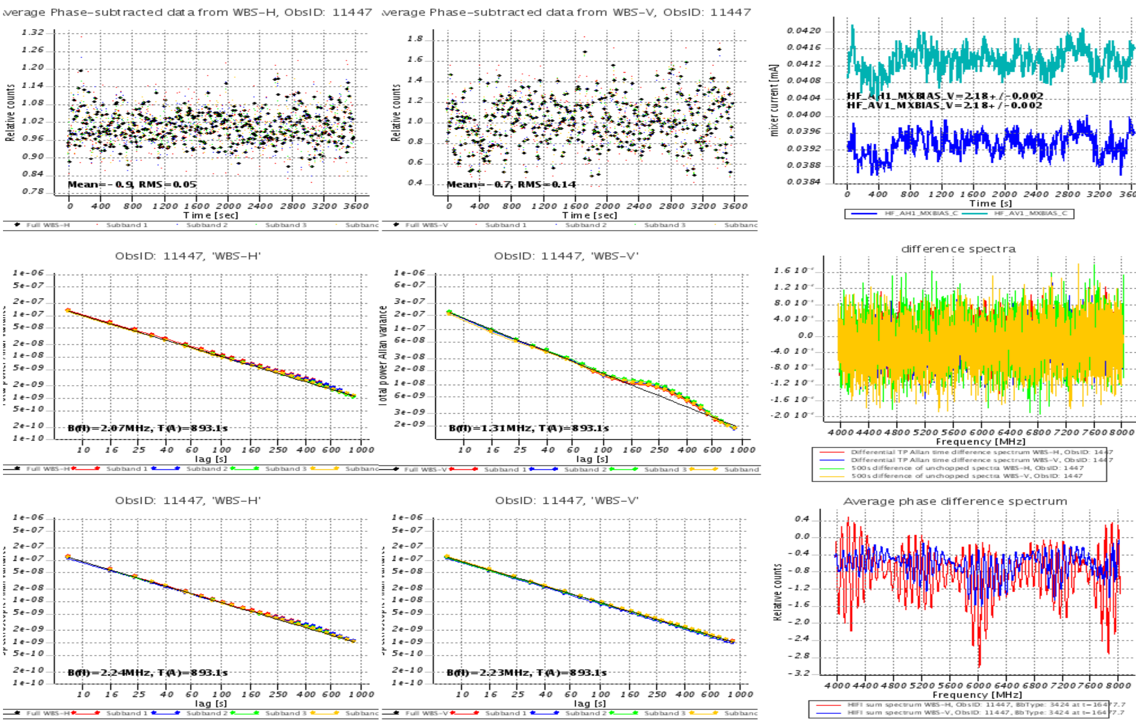


Fig. 88 B3a Load Chop differential stability for 3600s. 500s baseline quality looks good.

6.1.5 B4a 982 GHz Load-Chop

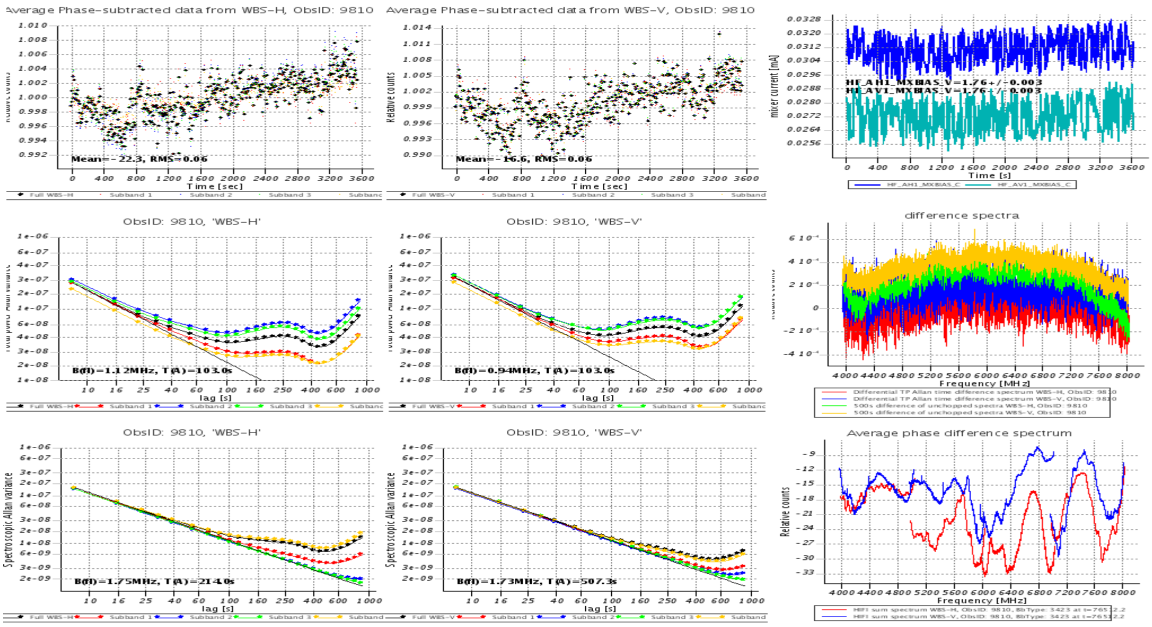


Fig. 89. B4a Load Chop differential stability for 3600s. 500s baseline quality shows diplexer passband.

6.1.6 B6a 1457 GHz Load-Chop (NII).

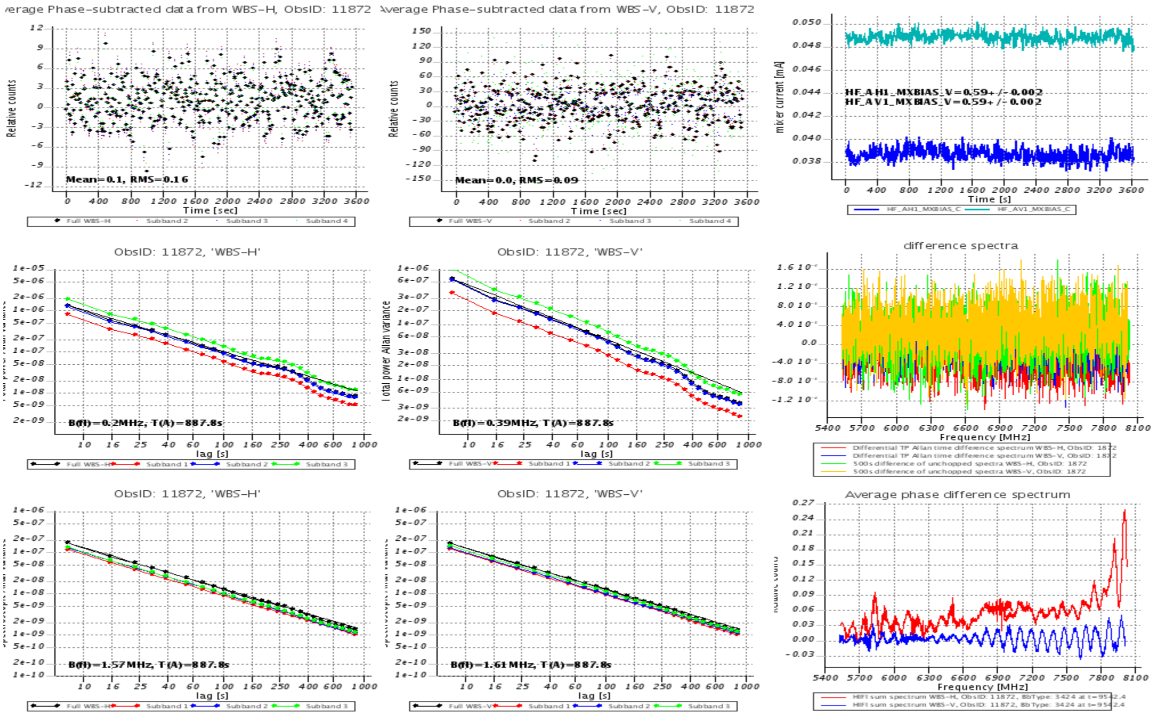


Fig. 90. B6a Load Chop differential stability for 3600s. 500s baseline has some fast structure embedded (microphonic standing wave modulation?). At this frequency the system stability is very poor! Data taken in 4s slow chop mode.

6.1.7 B6b 1674 GHz Load-Chop

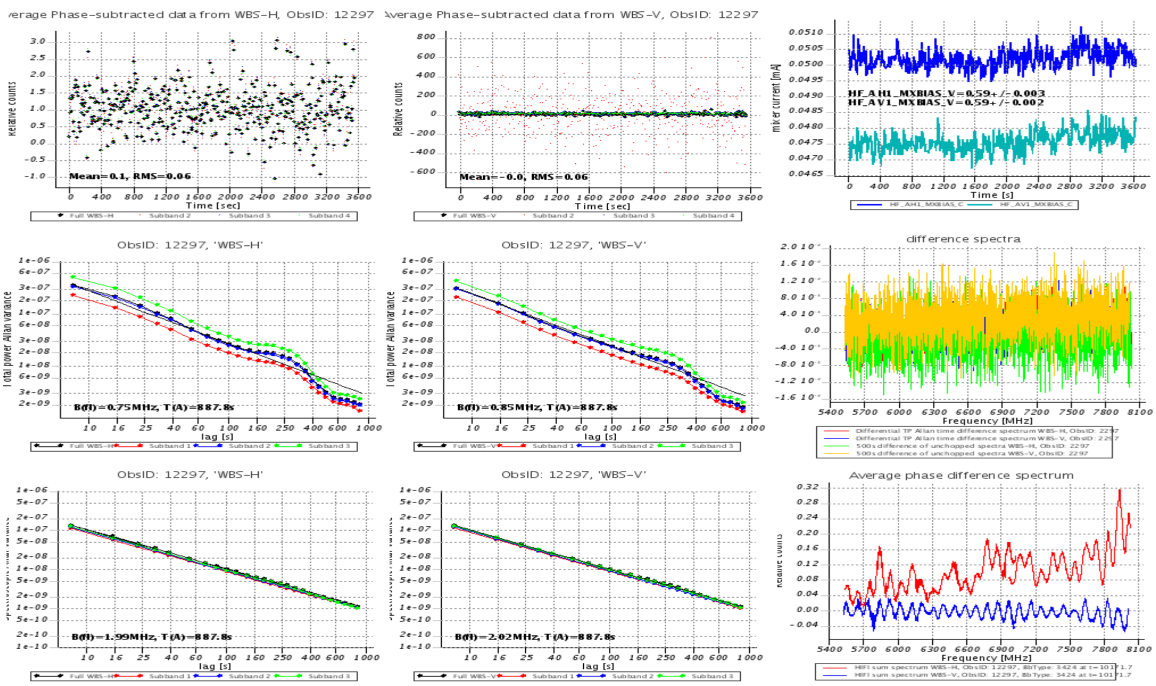


Fig. 91. B6b Load Chop differential stability for 3600s. 500s baseline quality looks quite good, albeit with some rapidly varying structure (microphonic LO-Mixer standing wave modulation?)

6.1.8 B7a 1720 GHz Load-Chop

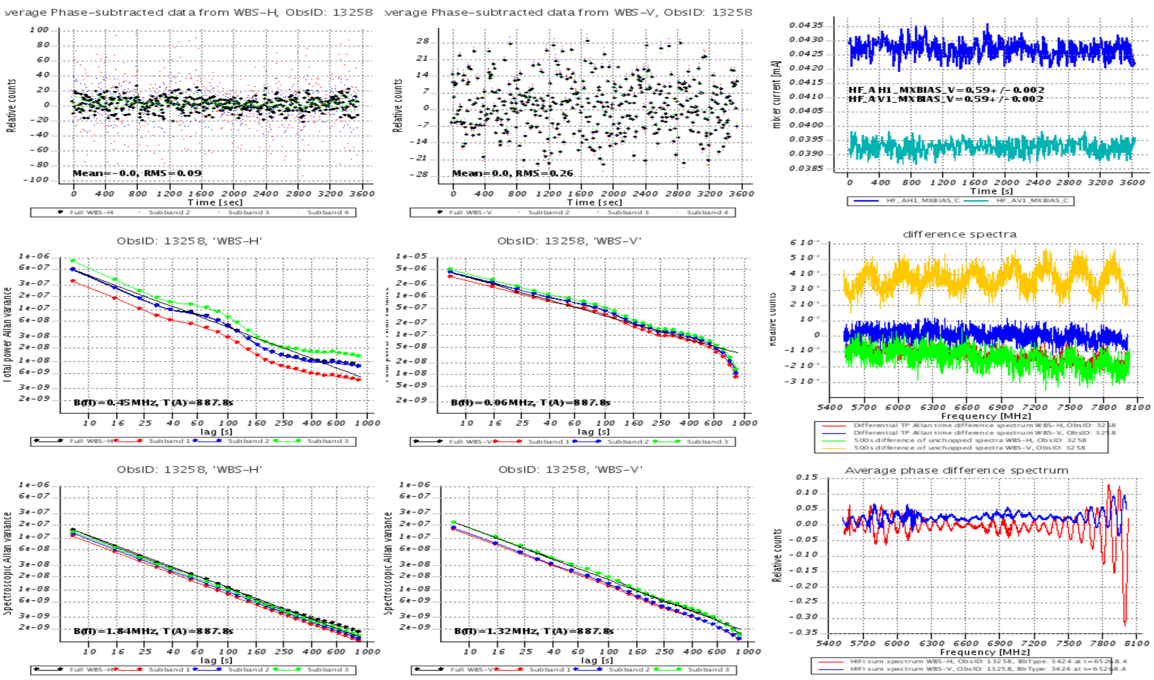


Fig. 92. B7a Load Chop differential stability for 3600s. 300 MHz IF ripple visible in the 500s baseline (does not subtract). This is due to the electro-thermal feedback in the IF. A minute change in LO power at the signal port changes the HEB mixer IF impedance, and hence IF reflection/heating.

6.1.9 B7b 1728 GHz Load-Chop

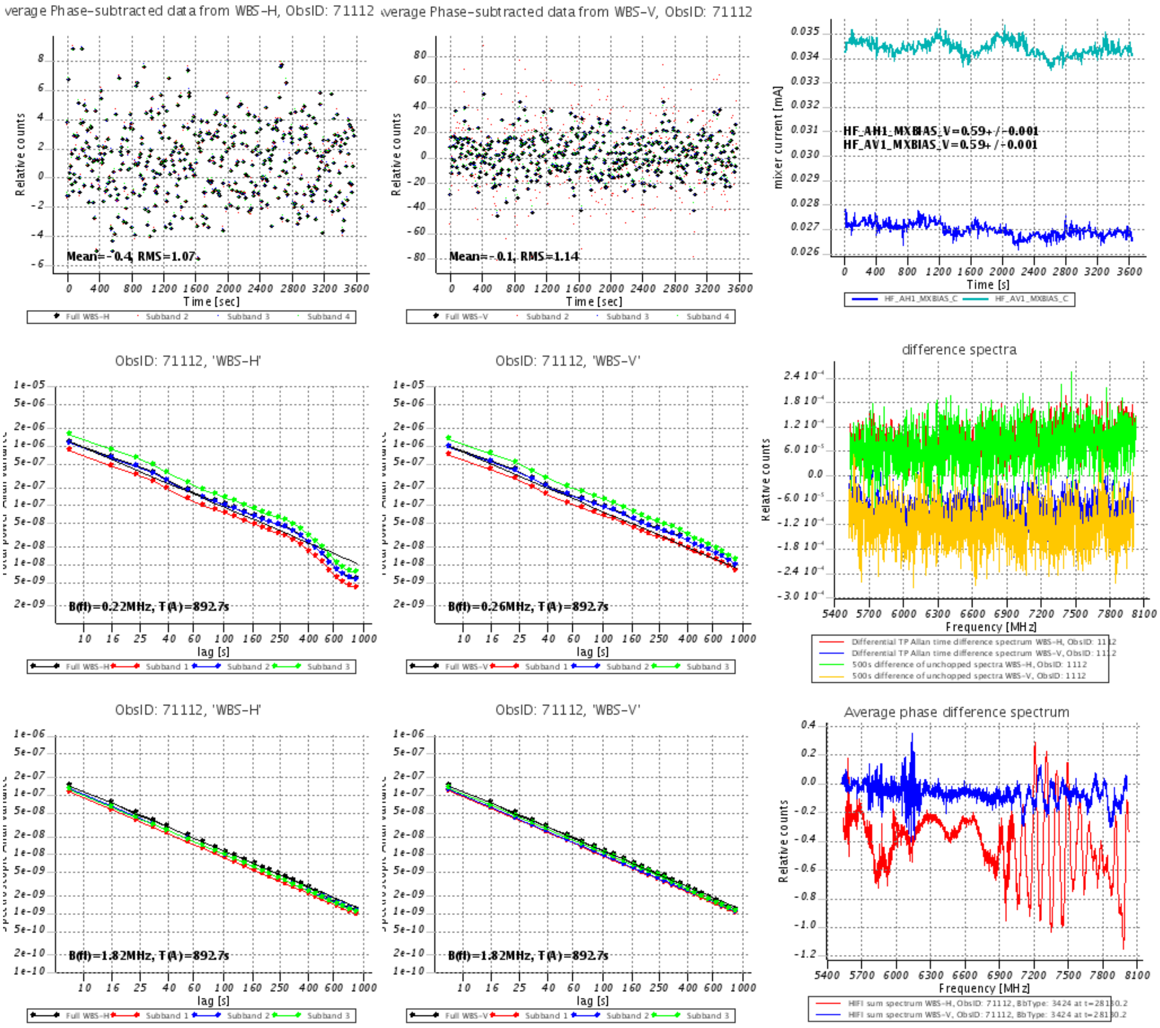


Fig. 93. B7b, edge of the band. The edges of B7b are the most stable (Fig. 82). Unfortunately no Load-Chop data was taken in the center of B7b, or at the C+ (1989 GHz) LO frequency. This is left for TV/PV. The 500s baseline looks reasonable with some fast fluctuations superimposed (LO-Mixer standing wave modulation?) Mode; 4s slowchop.

6.2 Beam Switch (DBS) Differential Stability

Objectives

To simulation beam switching, verify the differential stability between two positions on the external cold load. This test will provide information on instability due to broadband gain variations, standing wave modulation, temperature drift…
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref].
Search for plat forming effects, baseline offsets
Provide input for the efficiency computation/loop-optimization AOT's.
Obtain Hot-Cold calibration loop parameter..

Test Procedure

```
Configure instrument, nominal bias, B-field, diplexer etc, stabilize if necessary
for mixer_band = 1, 5 do begin  {
    select both WBS, HRS low resolution mode  (4 second readout)
    select focal plane chopper, slow chop mode
      for freq = flo1, flo2     {          (2 LO frequencies near the edge of the band)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
            for i = 0, 450 do {                              (1 hour)
              for i2 = 0, 1 do {                             (loop 2x)
                select chopper external Cold BB, position 1
                acquire WBS/HRS spectrum {2sec}
                select chopper external Cold BB, position 2
                acquire WBS/HRS spectrum {2sec}
              }
            }
      }
}
end
```

<u>**CUS script name:**</u>

- *Testmode_stability_loadchop (1hour/measurement)*

Note1: Total integration time 60 minutes * 2.
Note2: Symmetric chop: Pc, Pc', Pc', Pc…
Housekeeping data should be acquired and stored throughout this and other test procedures.

Result

The total power and spectroscopic system gain stability between two positions on the external CBB as a function of integration time in load-chop mode for each mixer band.
Knowledge of plat forming spectrometers, systematic baseline offsets
Loop parameters AOT
Not included in the results are possible standing wave modulation in the telescope structure.

6.2.1 B2b 758 GHz Double beam Switch (DBS)

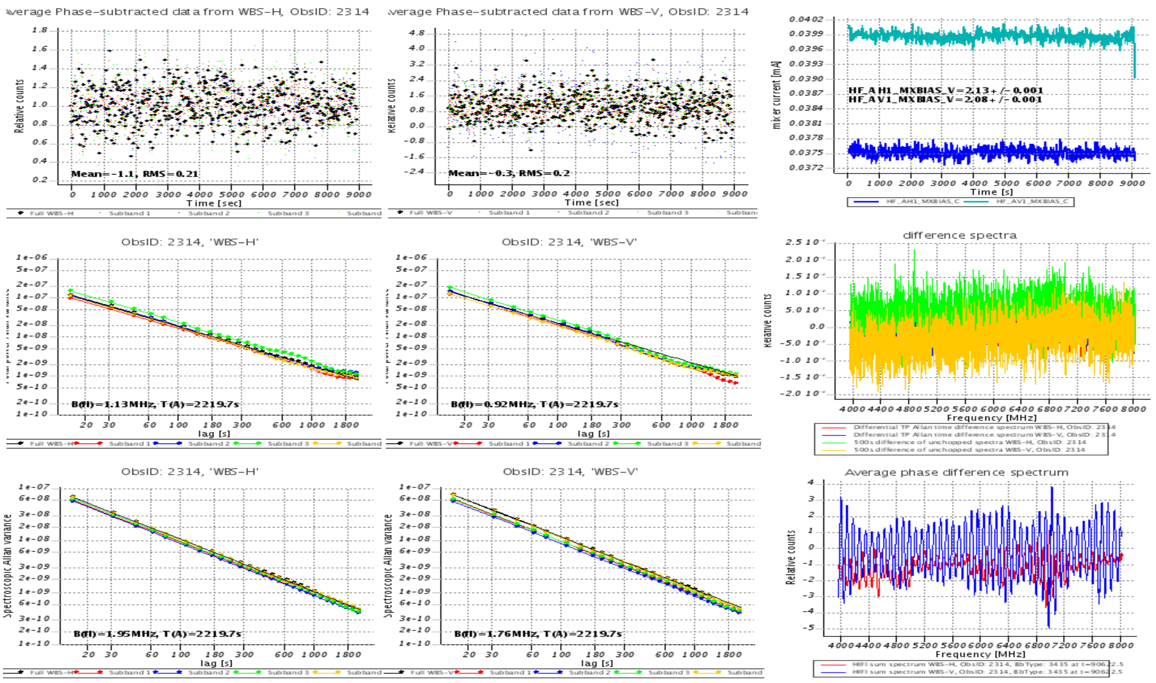


Fig. 94. B2b DBS differential stability for 9000s. 500s baseline quality looks quite good, except for Subband4 (7-8 GHz).

6.2.2 B3a 841 GHz Double beam Switch (DBS)

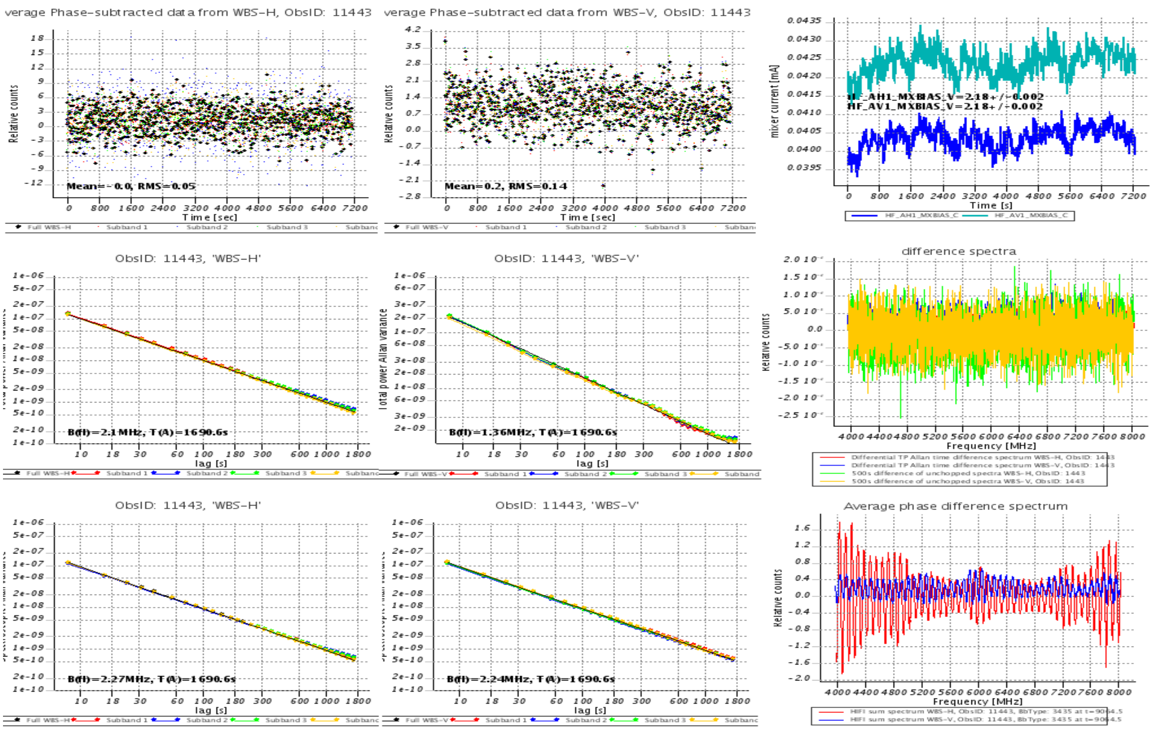


Fig. 95. B3a DBS differential stability for 7200s. 500s baseline quality looks very good.

6.2.3 B4a 982 GHz Double beam Switch (DBS)

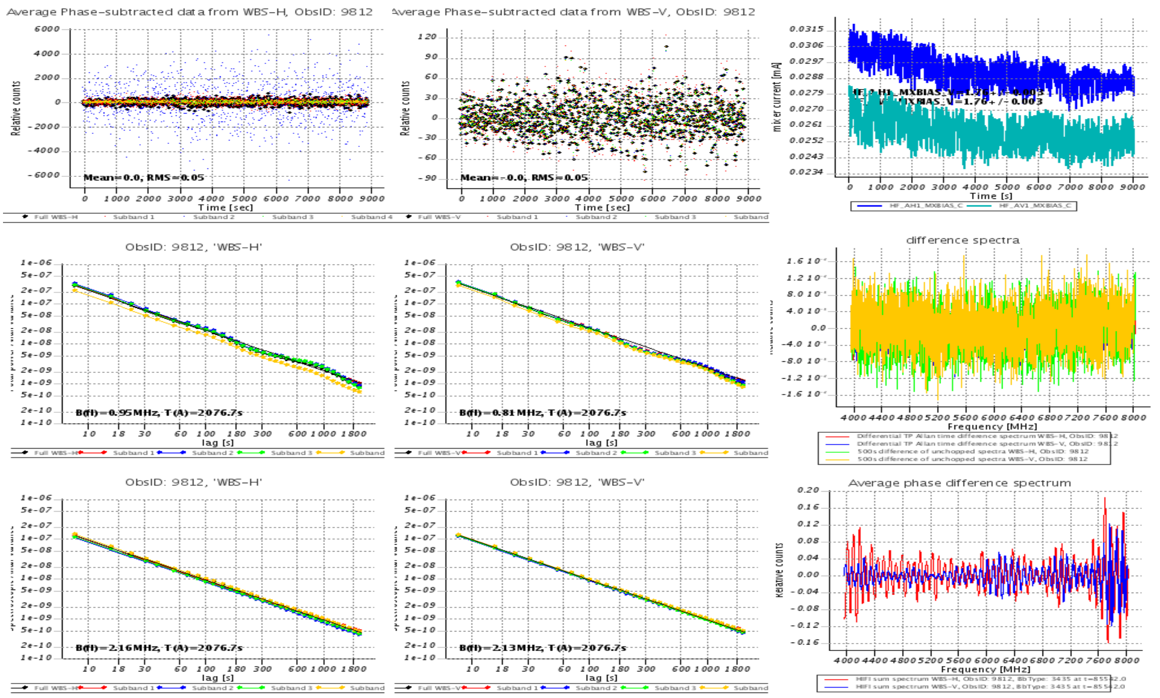


Fig. 96. B4a DBS differential stability for 9000s. Some evidence of instability in the 500s baseline, possible a standing wave problem.

6.2.4 B6a 1457 GHz Double beam Switch (DBS)

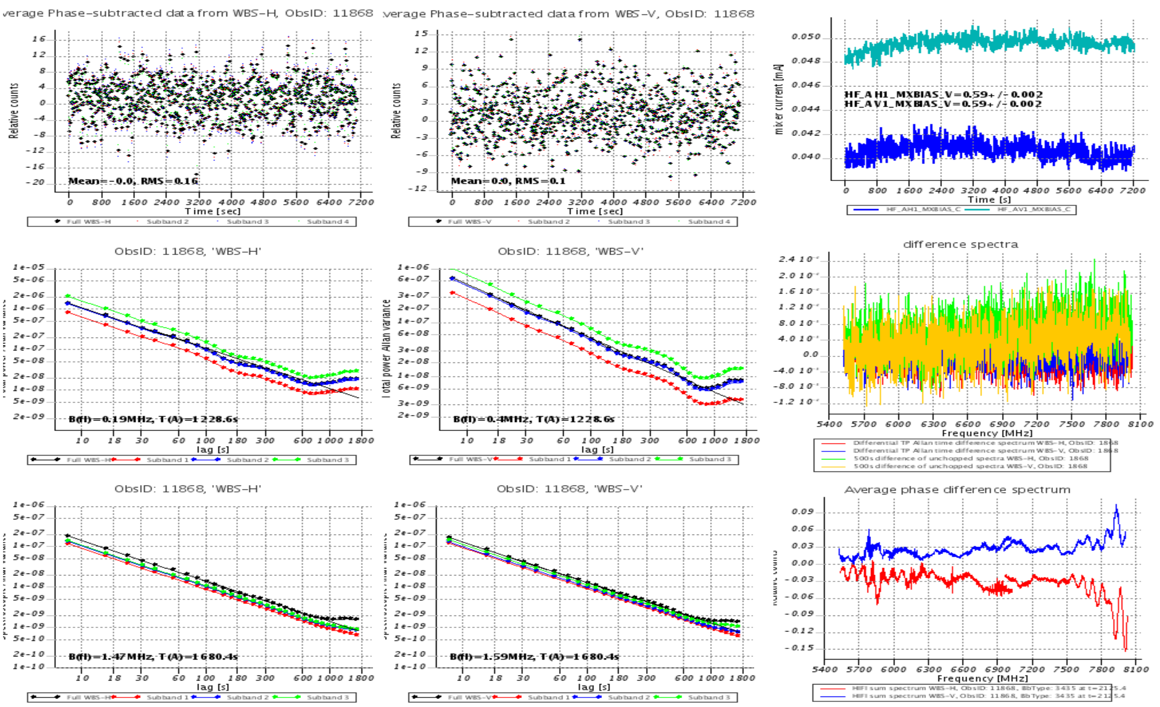


Fig. 97. B6a DBS differential stability for 3600s. Some evidence of instability in the 500s baseline, possible a microphonic standing wave modulation problem from the LOU/FPU hybrid cryostats.

6.2.5 B6b 1673 GHz Double beam Switch (DBS)

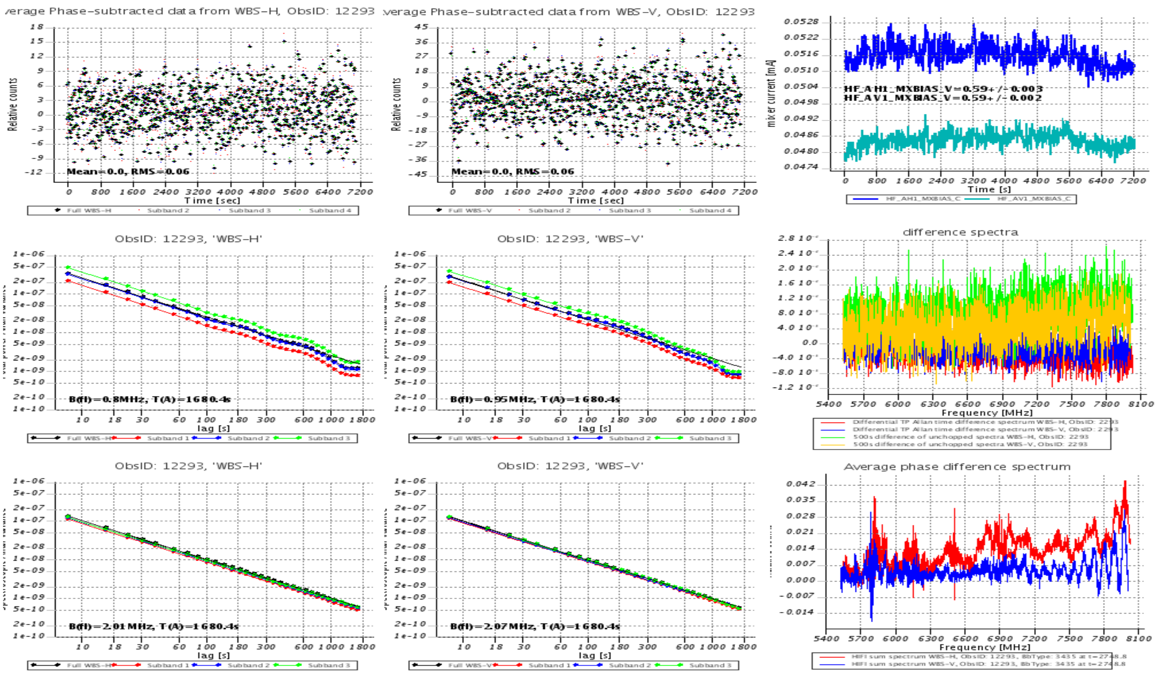


Fig. 98. B6b DBS differential stability for 3600s. IF instability in the 500s baseline (no perfect subtraction, see caption Fig. 92) .

6.2.6 B7a 1720 GHz Double beam Switch (DBS)

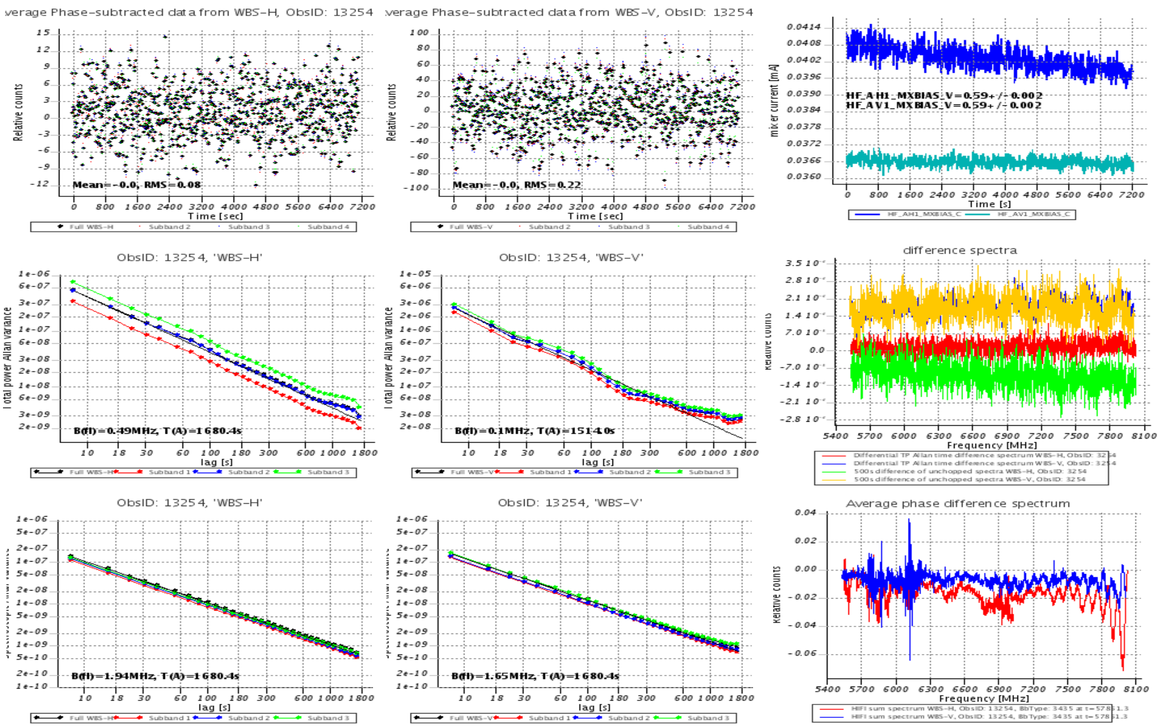


Fig. 99. B6a DBS differential stability for 3600s. IF instability in the 500s baseline (no perfect subtraction, see caption Fig. 92).

6.2.7 B7b 1728 GHz Double beam Switch (DBS)

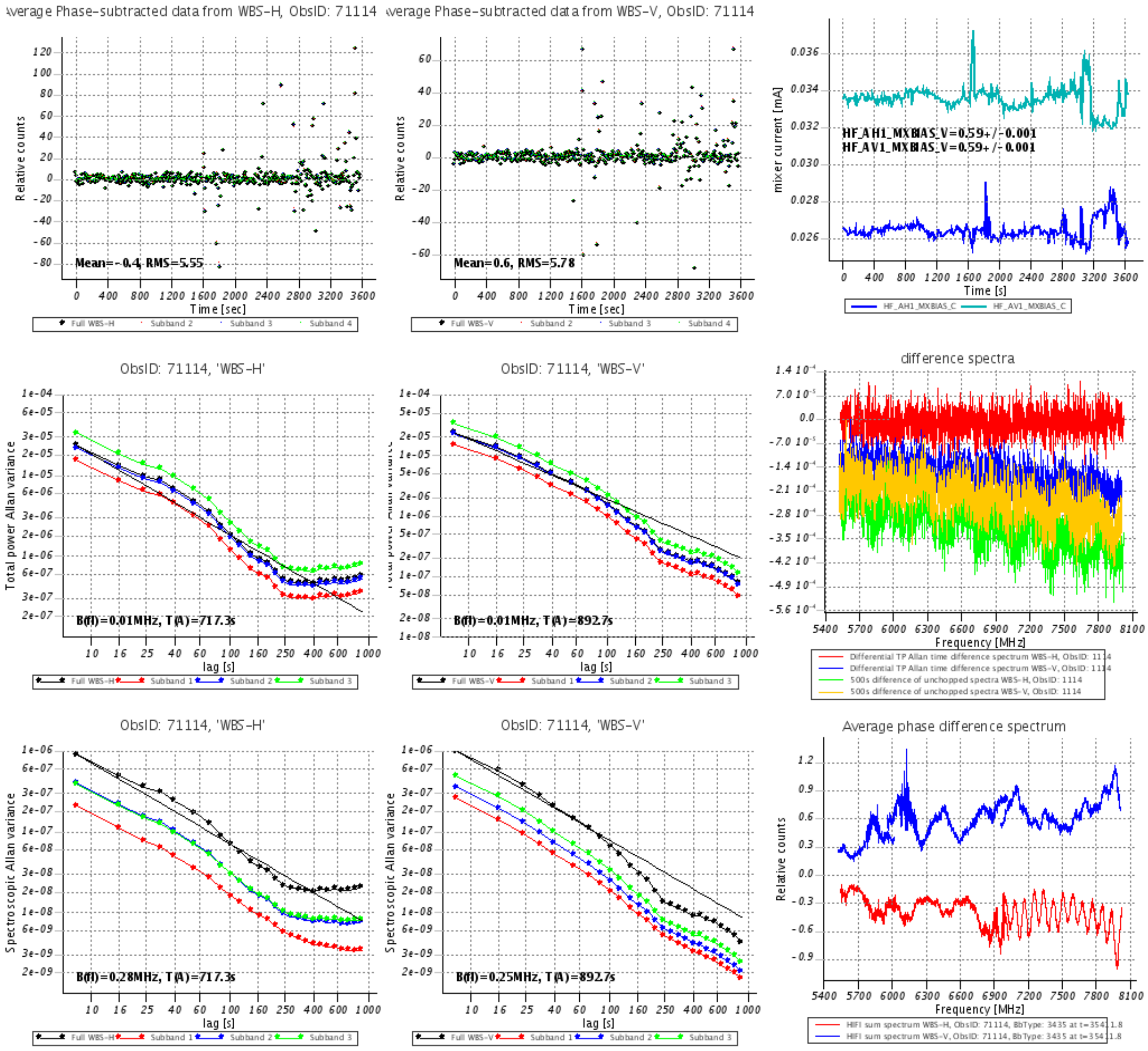


Fig. 100. B7b DBS differential stability for 3600s. . IF instability in the 500s baseline (no perfect subtraction, see caption Fig. 91). Note that 1728 GHz is near the band edge, and a more stable frequency for b7b. Unfortunately no data was taken in the center range of B7b during the ILT-FM.

6.3 Internal Load Differential Stability

Objectives

Verify the internal Hot/Cold calibration load differential amplitude stability of HIFI instrument, due to broadband gain variations, standing wave modulation, temperature drift…
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref]..
Search for plat forming effects, baseline offsets
Provide input for the efficiency computation/loop-optimization AOT's.
Obtain Hot-Cold calibration loop parameter...

Test Procedure

```
Configure instrument, nominal bias, B-field etc, stabilize if necessary
for mixer_band = 1, 5 do begin  {
    select both WBS, HRS low resolution mode  (4 second readout)
    select focal plane chopper, slow chop mode.
      for freq = flo1, flo2     {           (2 LO frequencies near the edge of the band)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
           for i = 0, 450 do {                            (1 hour)
             for i2 = 0, 1 do {                           (loop 2x)
               select chopper internal Cold BB
               acquire WBS/HRS spectrum {2sec}
               select chopper internal Hot BB
               acquire WBS/HRS spectrum {2sec}
             }
           }

      }
}
end
```

<u>CUS script name:</u>

- *Testmode_stability_internal_load (1hour/measurement)*

Note1: Total integration time 60 minutes * 2.
Note2: Symmetric chop; Pc, Ph, Ph, Pc…
Housekeeping data should be acquired and stored throughout this and other test procedures.\

Result

The total power and spectroscopic system gain stability between internal CBB and internal HBB as a function of integration time in load-chop mode for each mixer band.
Dependence of stability on the temperature (LO standing wave) environment.
Knowledge of plat forming spectrometers, systematic baseline offsets
Loop parameters AOT

6.3.1 B1a 531 GHz Int. Load Differential Stability

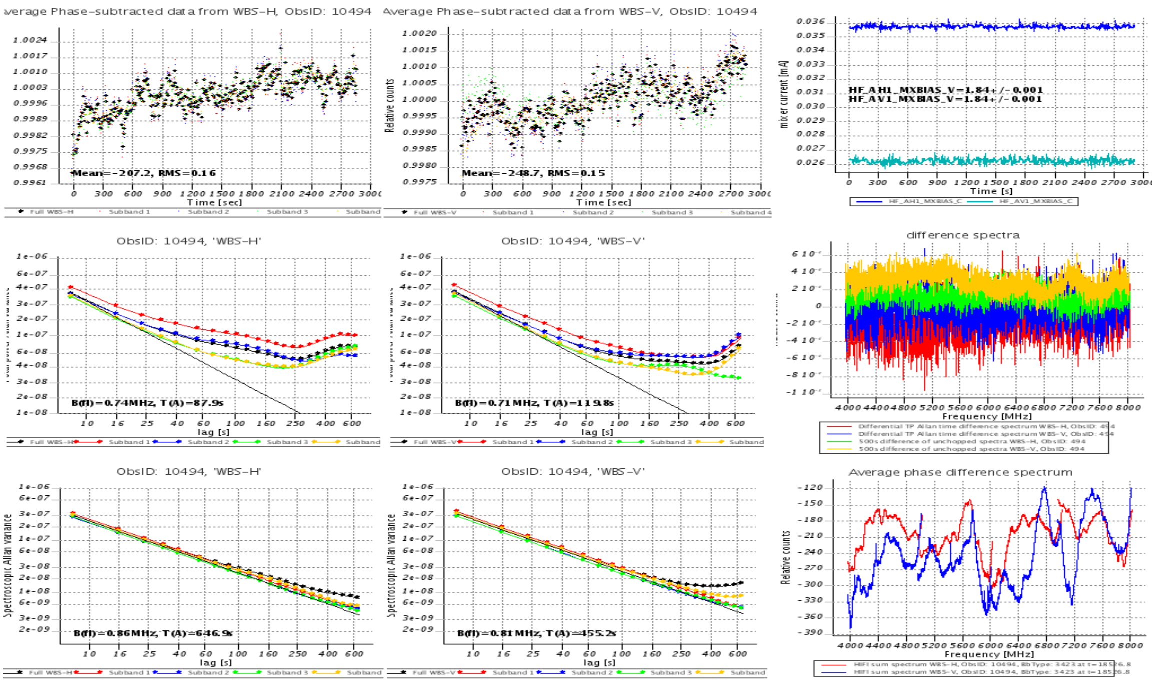


Fig. 101. B1a Int. Load differential stability for 3600s. Some instability in the 500s baseline due to a standing wave change between Int CBB, Int HBB.

6.3.2 B2a 686 GHz Int. Load Differential Stability

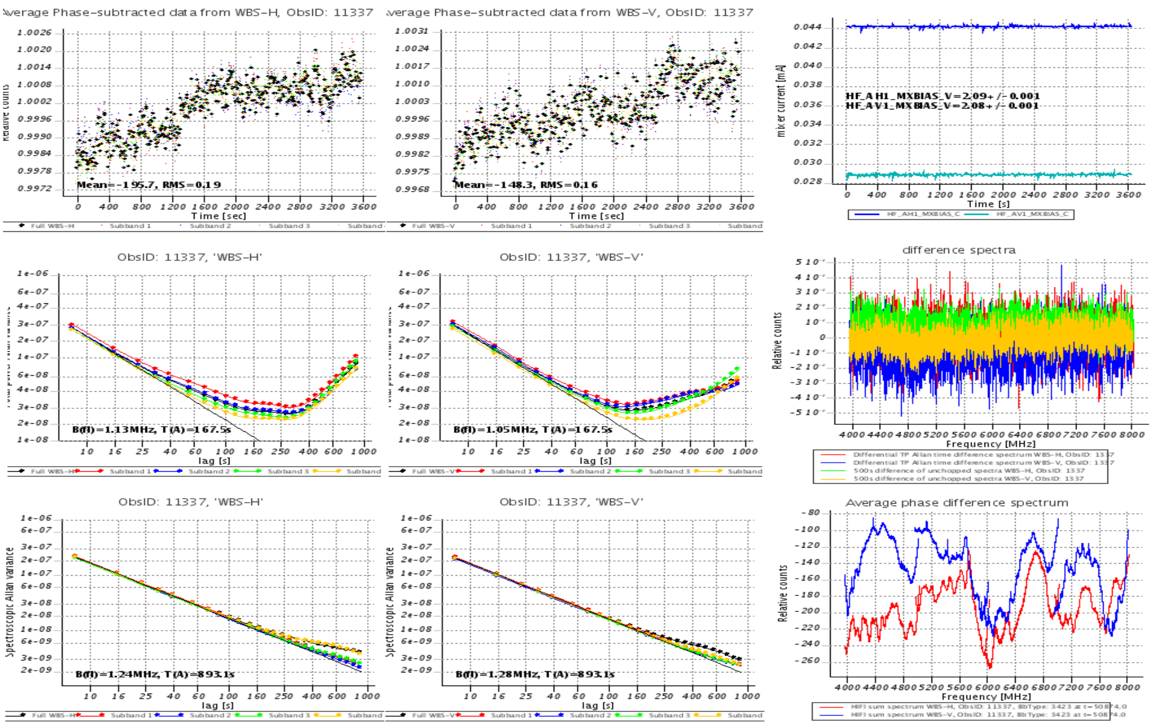


Fig. 102. B2a Int. Load differential stability for 3600s. 500s baseline looks reasonable.

6.3.3 B2b 758 GHz Int. Load Differential Stability

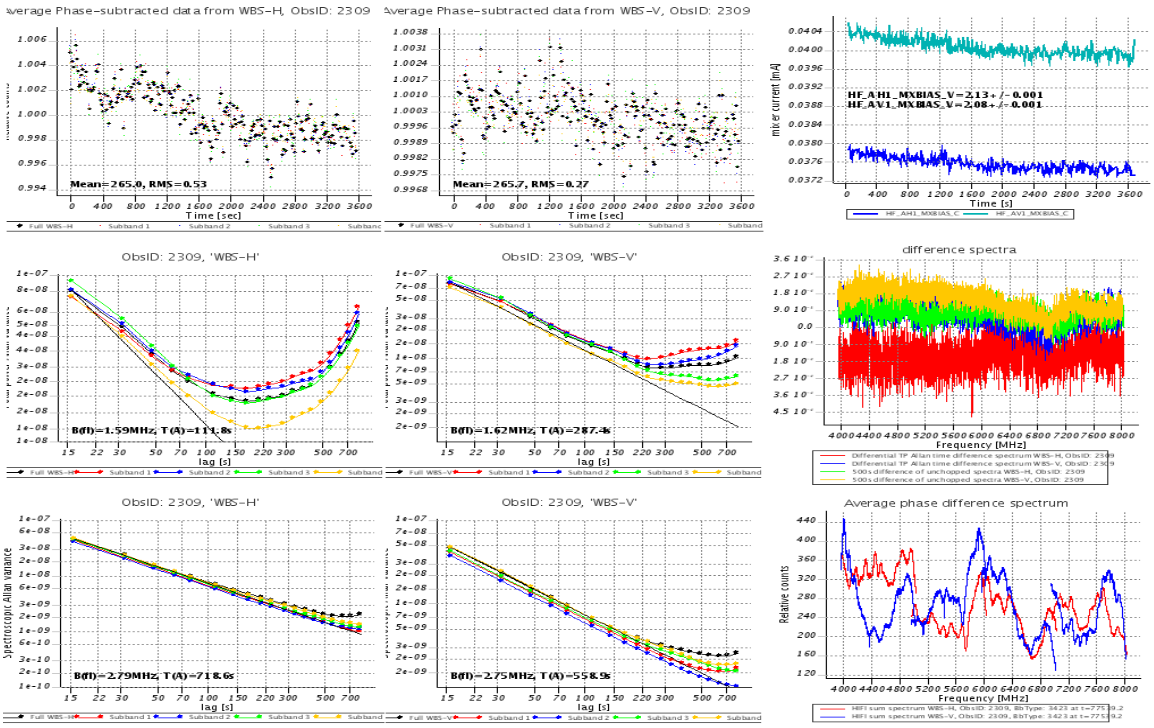


Fig.103. B2b Int. Load differential stability for 3600s. Some instability in the 500s baseline due to a standing wave change between Int CBB, Int HBB.

6.3.4 B3a 841 GHz Int. Load Differential Stability

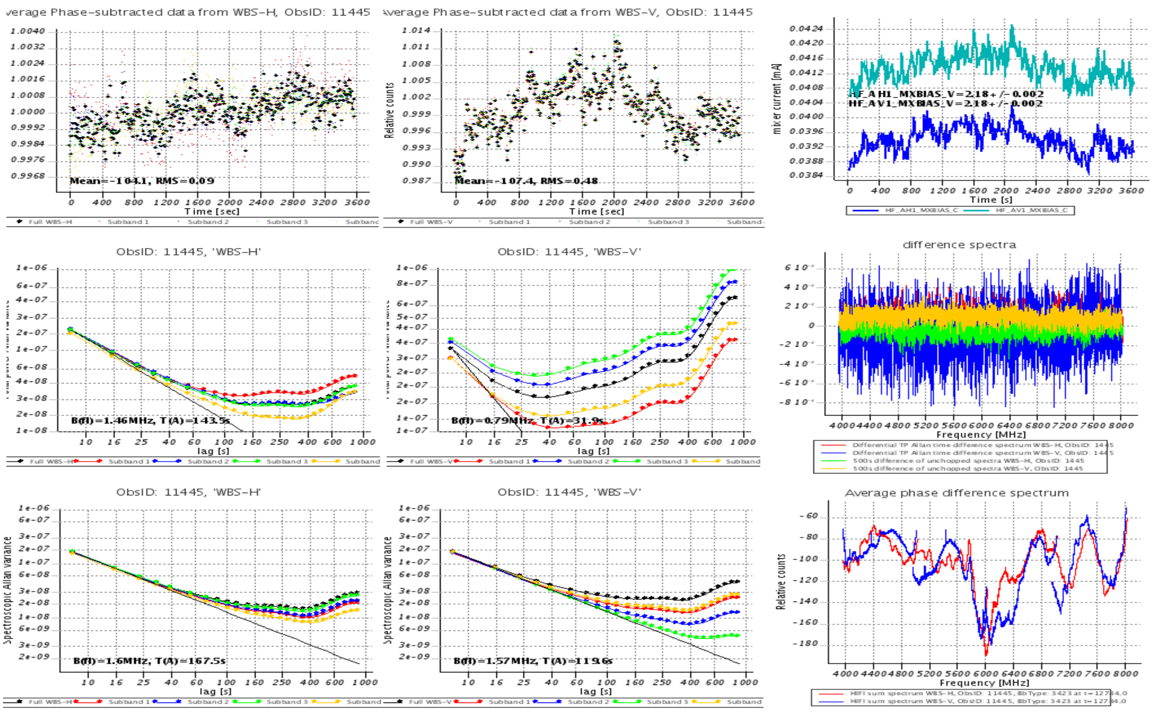


Fig. 104. B1a Int. Load differential stability for 3600s. 500s baseline looks quite nice.

6.3.5 B4a 982GHz Int. Load Differential Stability

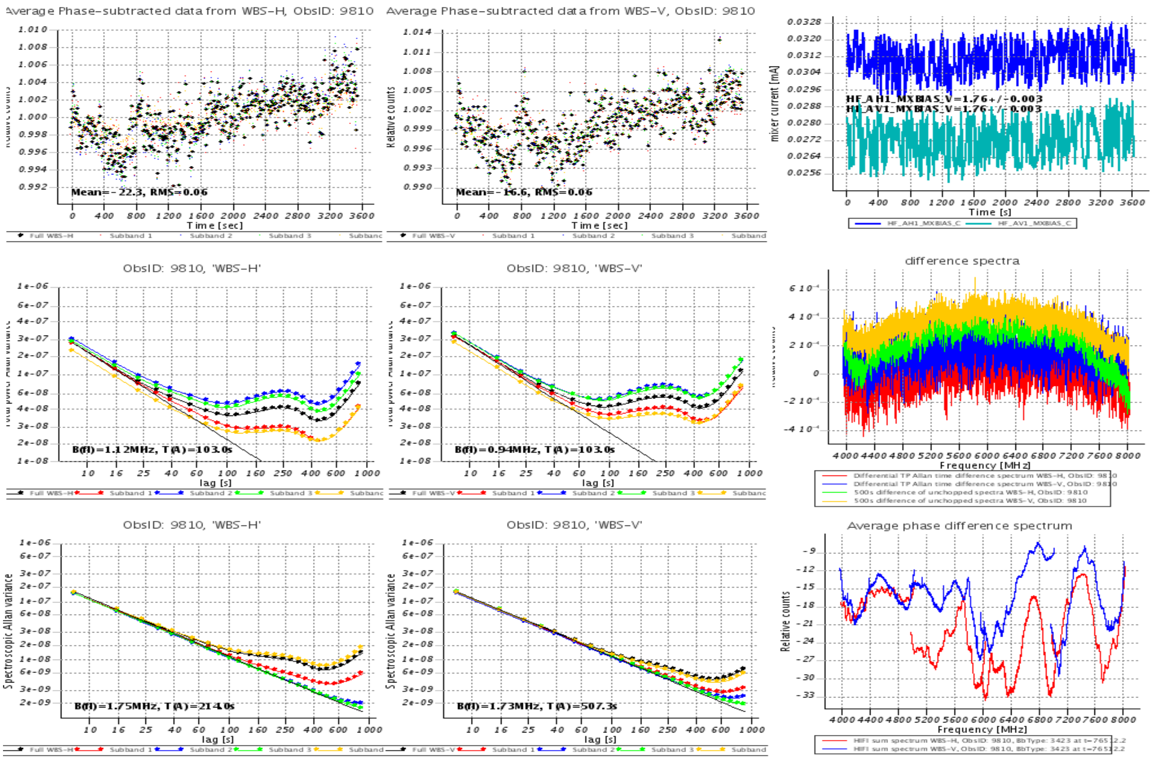


Fig. 105. B1a Int. Load differential stability for 3600s. Some instability in the 500s baseline due to a standing wave change between Int CBB, Int HBB. Diplexer passband visible.

6.3.6 B5b 1223 GHz Int. Load Differential Stability

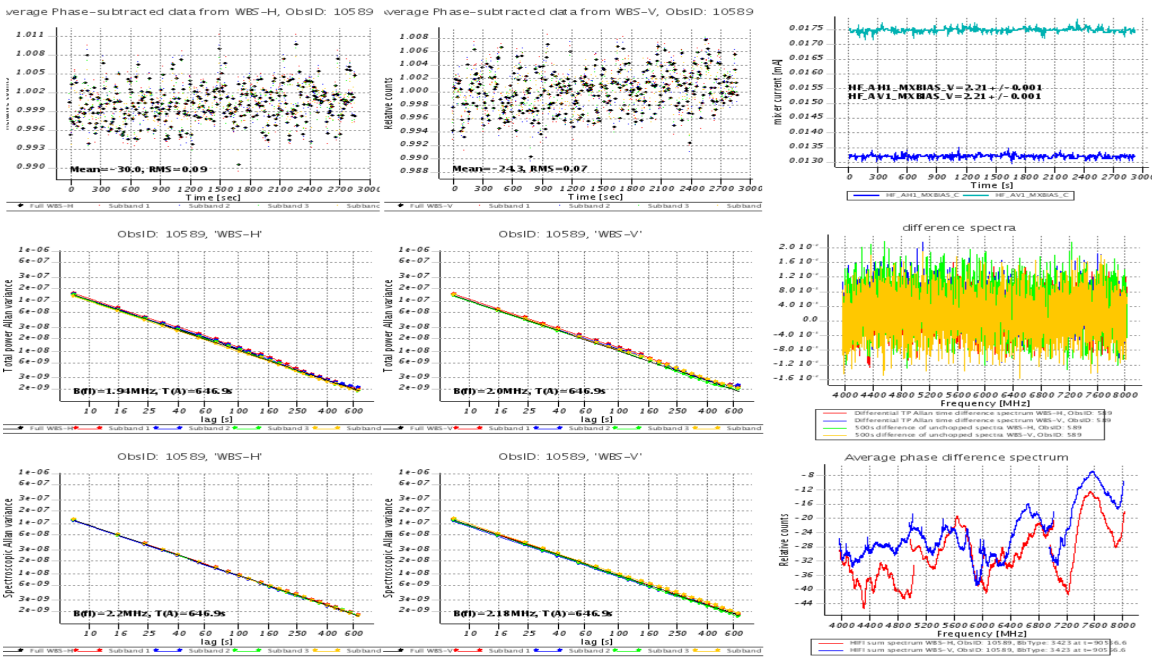


Fig. 106. B5b Int. Load differential stability for 3600s.

6.3.7 B6a 1457 GHz Int. Load Differential Stability

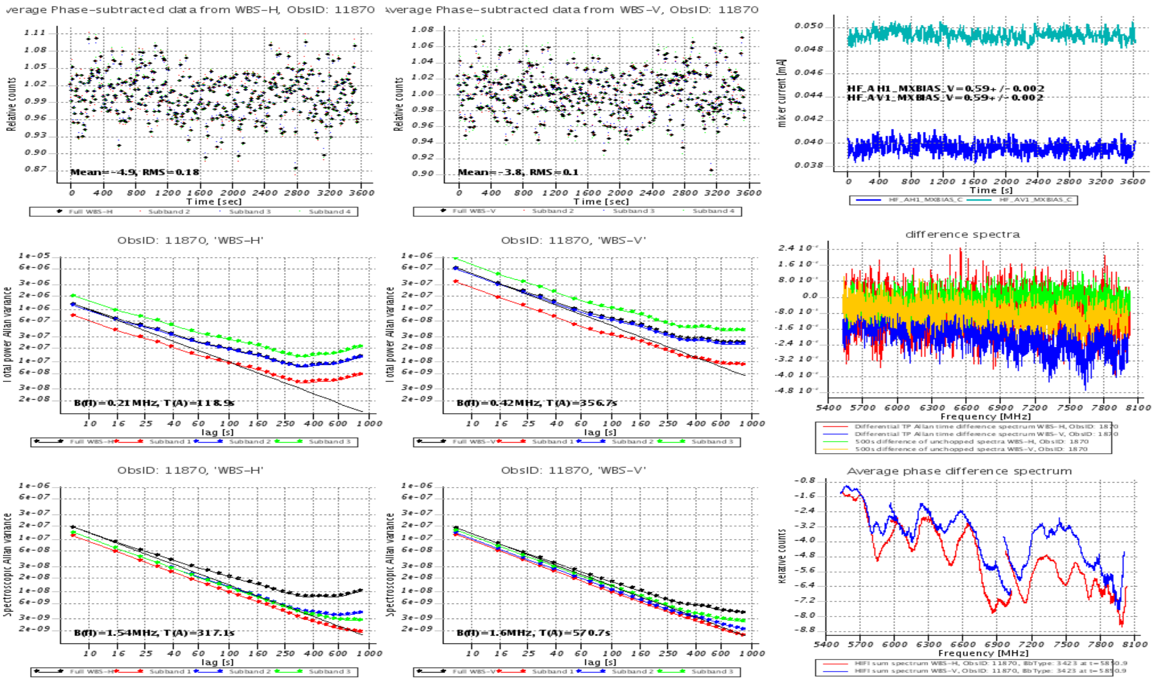


Fig. 107. B6a Int. Load differential stability for 3600s. Some instability in the 500s baseline due to a standing wave change between Int CBB, Int HBB.

6.3.8 B6b 16738 GHz Int. Load Differential Stability

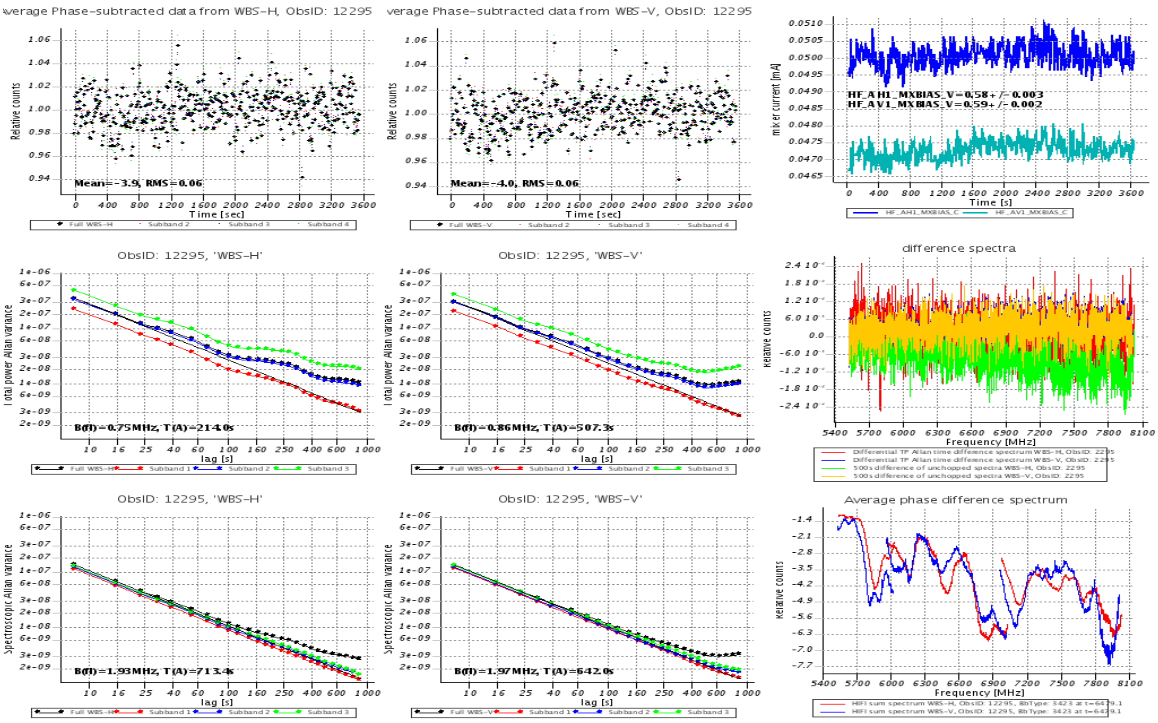


Fig. 108. B6b Int. Load differential stability for 3600s. Some instability in the 500s baseline possibly overlaid with a 300 MHz IF standing wave.

6.3.9 B7a 1720 GHz Int. Load Differential Stability

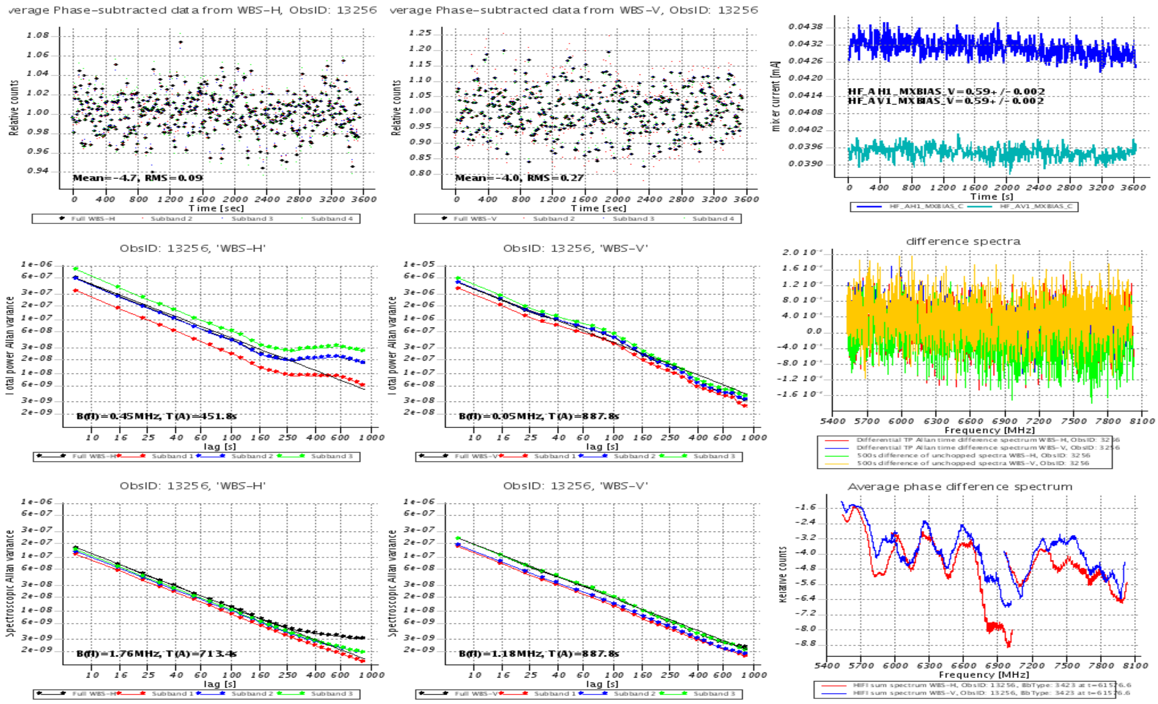


Fig. 109. . B7a Int. Load differential stability for 3600s. Some instability in the 500s baseline due to a standing wave change between Int CBB, Int HBB.

6.3.10 B7b 1728 GHz Int. Load Differential Stability

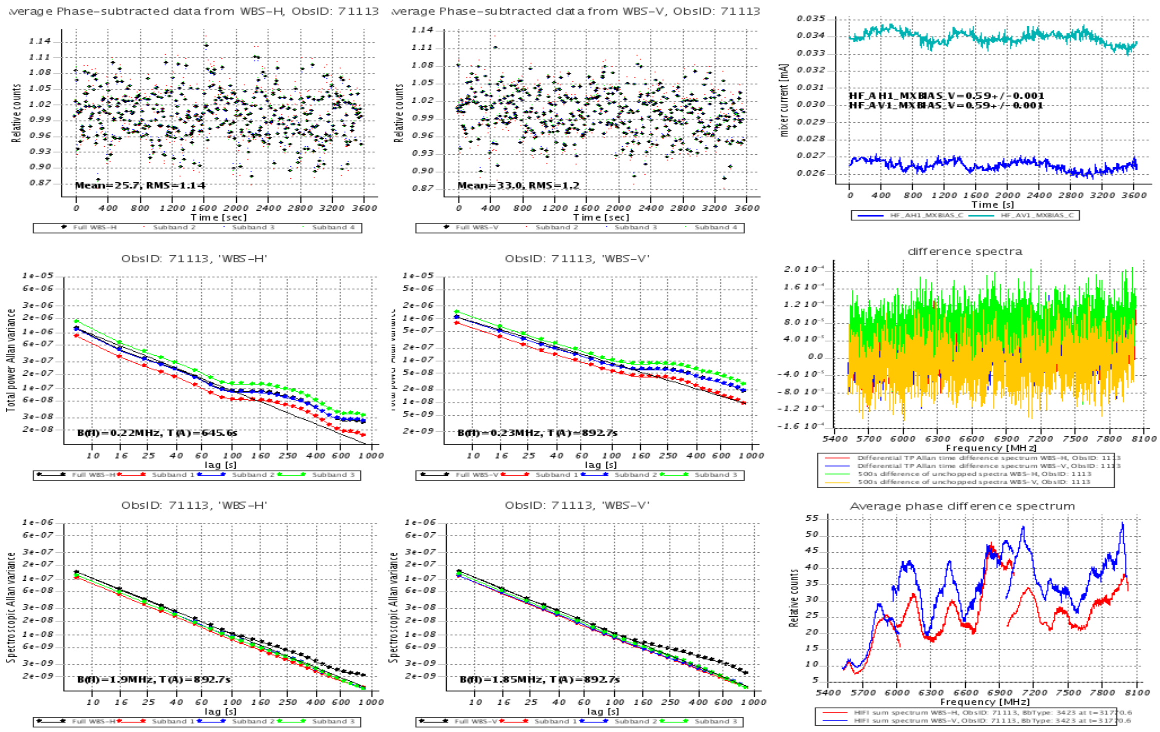


Fig. 110. B7b Int. Load differential stability for 3600s at a more stable LO frequency. Some (standing wave?) instability in the 500s baseline possibly overlaid with a 300 MHz IF standing wave.

6.4 Frequency Switch Differential Stability

6.4.1 Objectives

Verify the differential frequency stability of HIFI instrument for each band, due to broadband gain variations, standing wave modulation, temperature drift, change in LO signal amplitude.
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref].
Search for plat forming effects, baseline offsets.
Provide input for the efficiency computation/loop-optimization AOT's.
Parameters are LO frequency, frequency step, interval time.
Frequency switch stability time.

6.4.2 Test Procedure

```
Configure instrument, nominal bias, B-field, diplexer etc, stabilize if necessary
for mixer_band = 1, 5 do begin  {
    select both WBS, HRS low resolution mode  (4 second readout)
    frequency switch rate, 0.5Hz
    select Internal Cold BB
      for freq = flo1, flo2     {          (2 LO frequencies near the edge of the band)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
            for i = 0, 450 do {                              (1 hour)
              for i2 = 0, 1 do {                             (loop 2x)
                select delta_flo1
                acquire WBS/HRS spectrum {2sec}
                select delta_flo2
                acquire WBS/HRS spectrum {2sec}
              }
            }
      }
}
end
```

<u>**CUS script name:**</u>

- *Testmode_stability_freqswitch (1hour/measurement)*

Note1: Total integration time 60 minutes * 2.

6.4.3 Result

The total power and spectroscopic system gain stability in switched frequency mode for each mixer band.
Frequency switch stability time.
Dependence of stability on the temperature (LO standing wave) environment.
Knowledge of plat forming spectrometers, systematic baseline offsets
Loop parameters AOT

6.4.4 Frequency Switching Tabulated (all bands as measured).

		Frequency Switching [1, 2, 3]					
		145MHz		154MHz		164MHz	
band	Freq. (GHz)	*spec > 300s*		*spec > 300s*		*spec > 300s*	
Polarization		H	V	H	V	H	V
B1a	488-522						
B1b	566-628	>>200	>>200	>>200	>>200	>>200	>>200
B2a	642-710	>>200	>>200	>>200	>>200	>>200	>>200
B2b	724-793	>200	>200	>200	>200	100	200
B3a	807-852	>>200	>>200	>>200	>>200	>>200	>>200
B3b	866-953	>200	>200	>200	>200	>200	>200
B4a	980-1040	111	111	>200	>200	>200	>200
B4b	1065-1115						
B5a	1127-1178	>>200	>>200	>>200	>>200	>>200	>>200
B5b	1192-1242	>>200	>>200	>>200	>>200	>>200	>>200
B6a	1430-1570	< 16	32	32	32	80	80
B6b	1580-1690	>>200	100	>200	200	>>200	>200
B7a	1692-1845	170	40	>200	60	>200	>200
B7b	1719-1908	>200	>200	>=130	>200	>=130	>200

[1] LO-mixer cavity standing wave in ILT test setup 145 MHz

[2] Frequency switching for HEB bands 6, 7 very questionable

[3] Inclomplete data set due to a lack of time during the ILT phase.

Table 6. 15 minute FSW differential measurements around the primary 154 MHz Mixer-LO horn standing wave.

6.4.5 B1b Frequency switching (FSW), 622 GHz

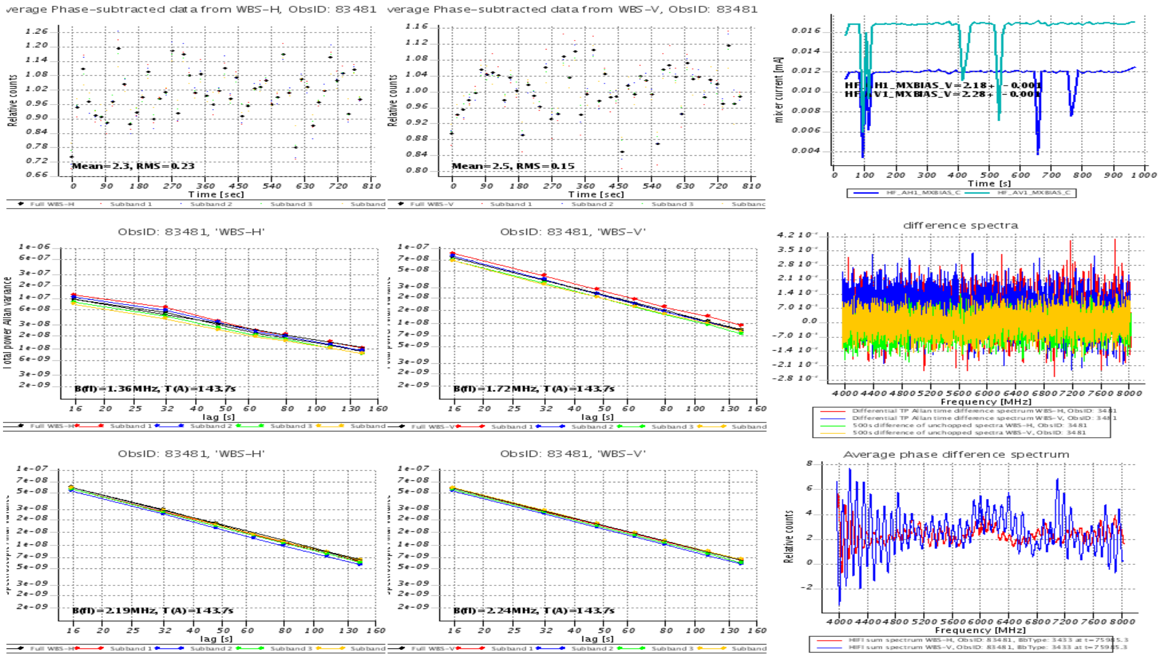


Fig. 111. B1b FSW for 900s. Throw 154 MHz. 500s baseline looks nice.

6.4.6 B2a Frequency switching (FSW), 700 GHz

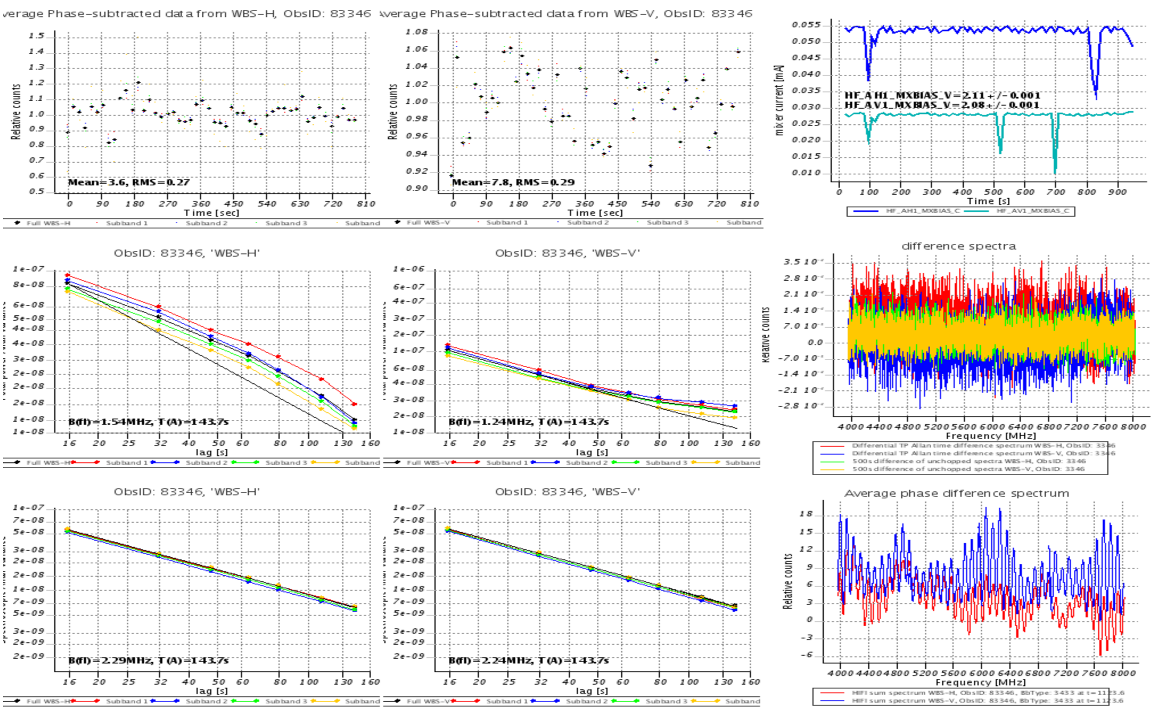


Fig. 112. B2a FSW for 900s. Throw 154 MHz. 500s baseline looks ok.

6.4.7 B3a Frequency switching (FSW), 837 GHz.

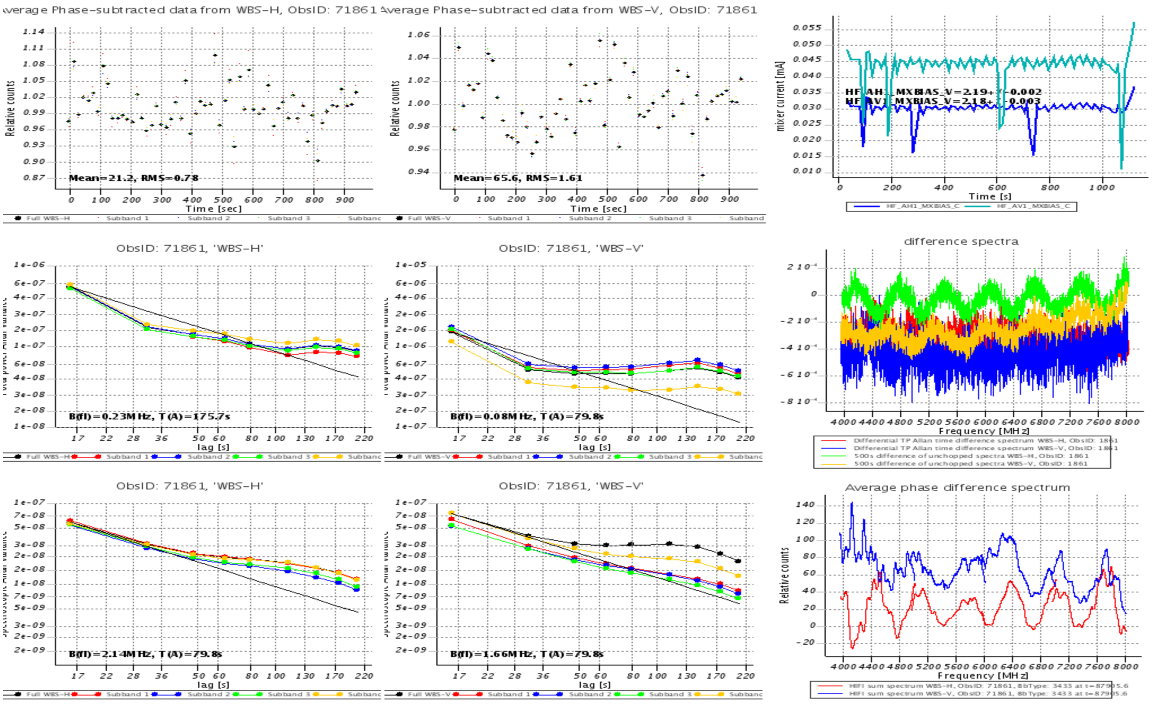


Fig. 113. B3a FSW for 900s. Throw 154 MHz. 500s baseline shows IF standing wave + some diplexer response.

6.4.8 B3b Frequency switching (FSW), 900 GHz.

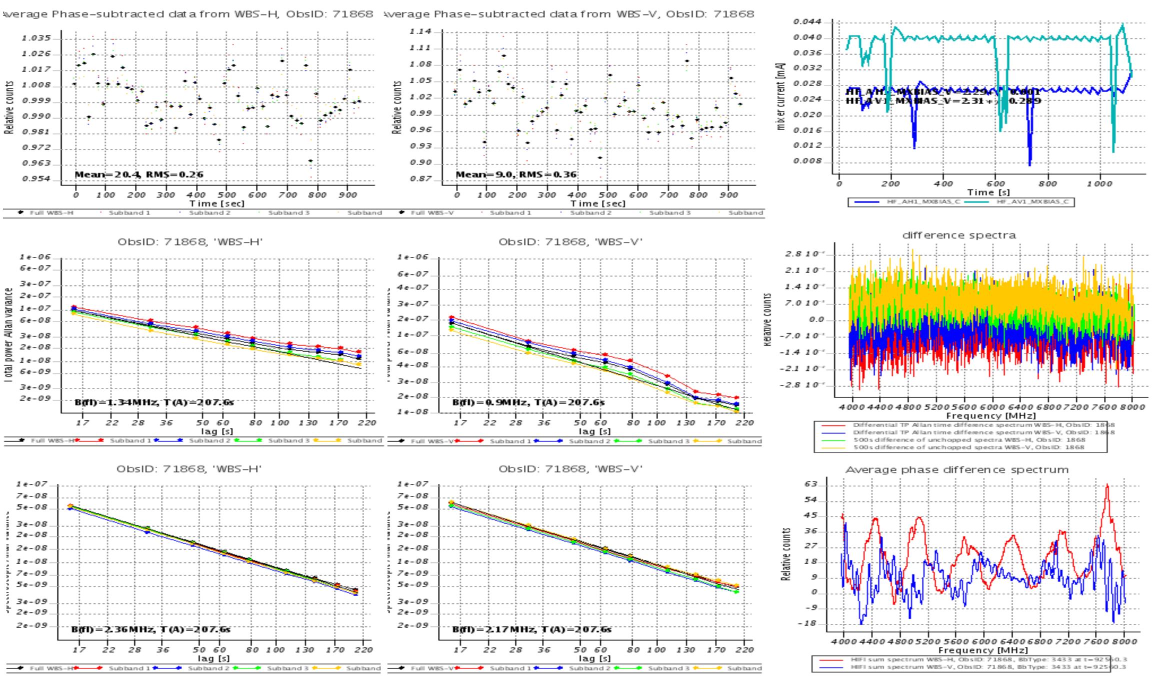


Fig. 114. B3b FSW for 900s. Throw 154 MHz. 500s baseline shows some instability.

6.4.9 B4a Frequency switching (FSW), 1023 GHz.

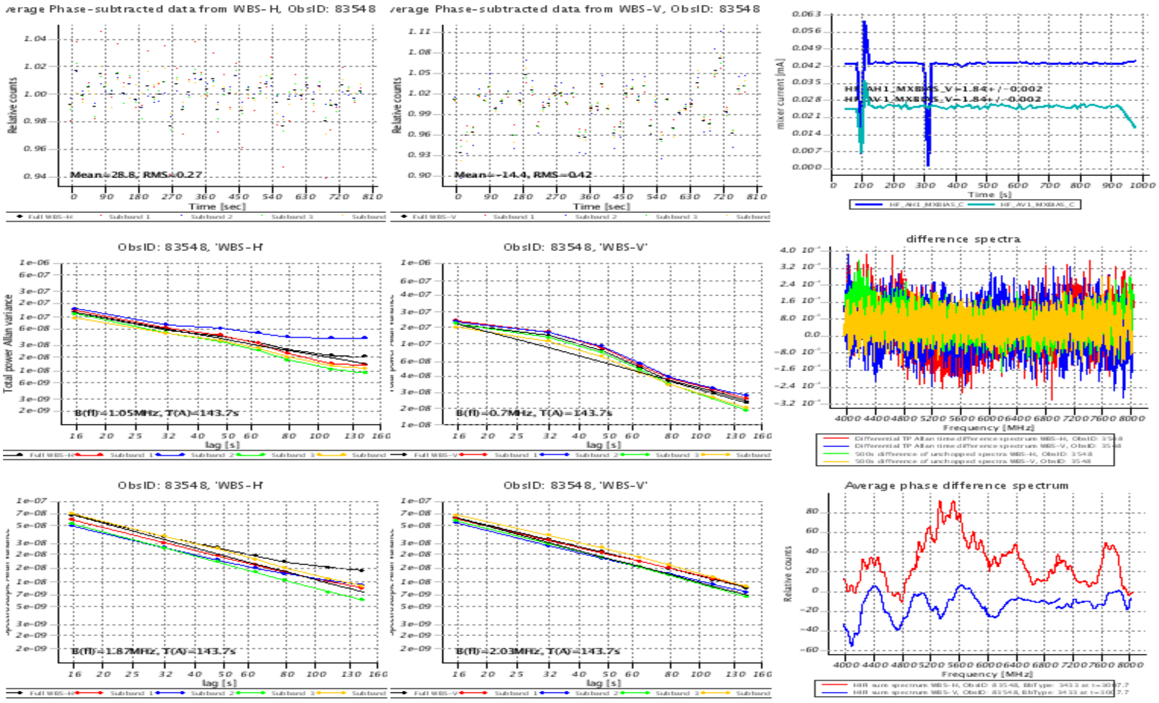


Fig. 115. . B4a FSW for 900s. Throw 154 MHz. 500s baseline looks ok.

6.4.10 B5a Frequency switching (FSW), 1185 GHz.

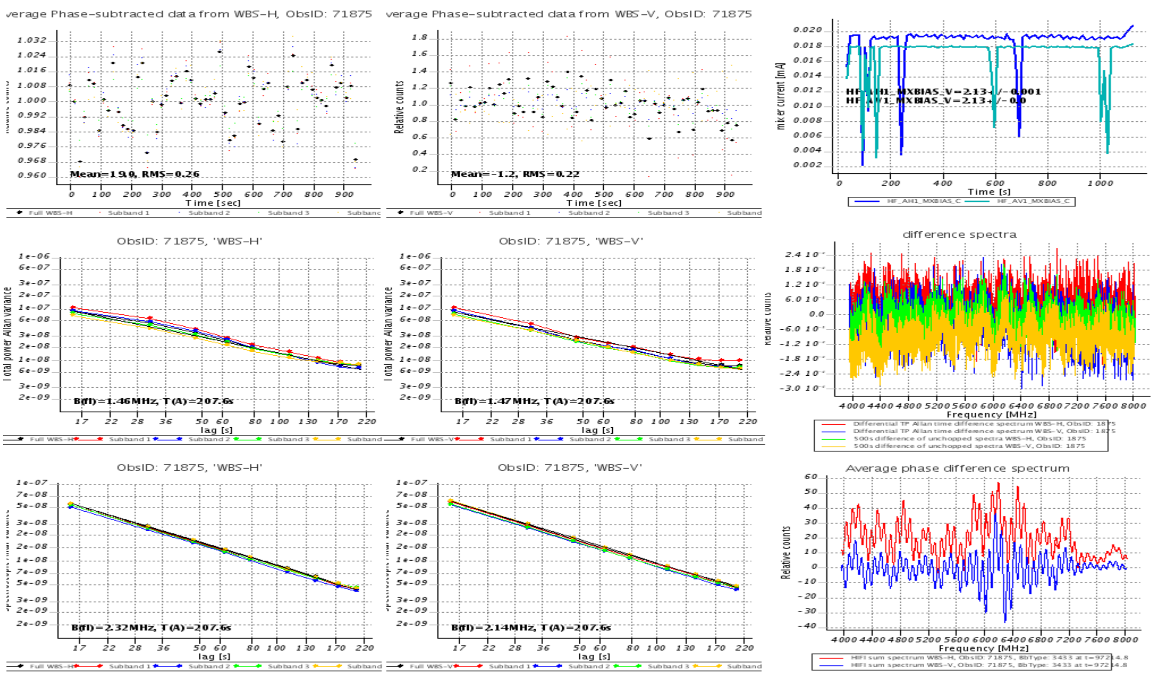


Fig. 116. . B5a FSW for 900s. Throw 154 MHz. 500s baseline shows LO-mixer cavity standing waves.

6.4.11 B6a Frequency switching (FSW), 1462 GHz, N II

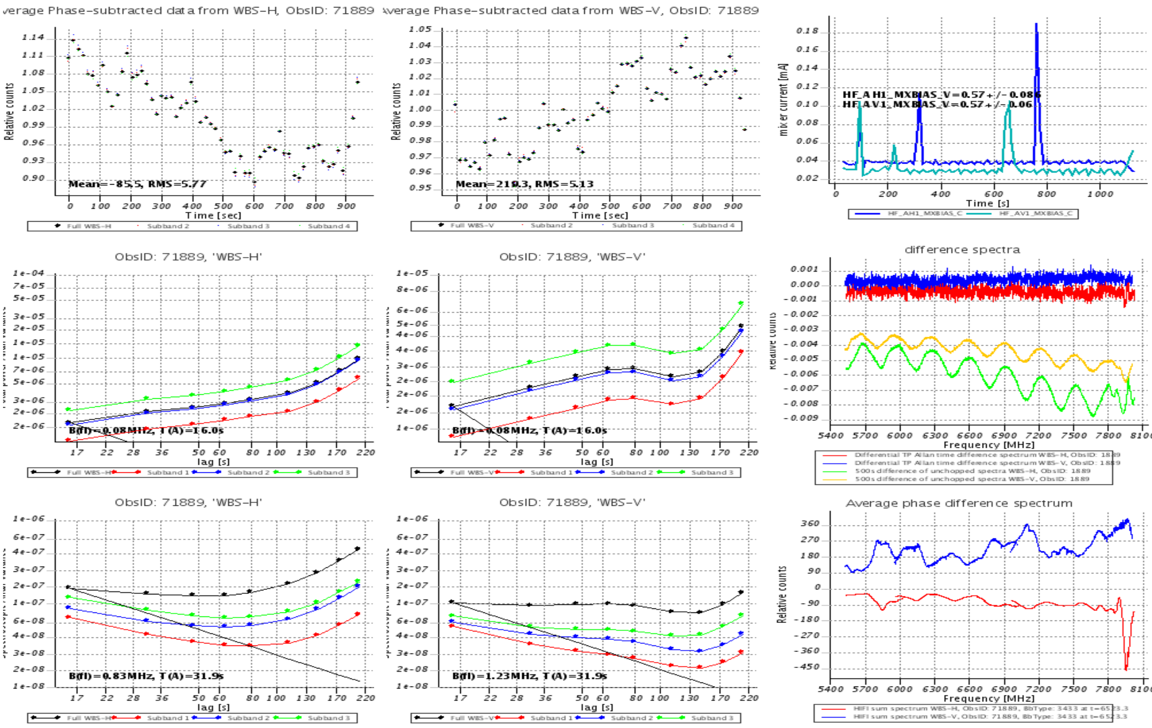


Fig. 117. B6a FSW for 900s. Throw 154 MHz. 500s baseline shows severe IF standing wave instability.

6.4.12 B6b Frequency switching (FSW), 1667 GHz.

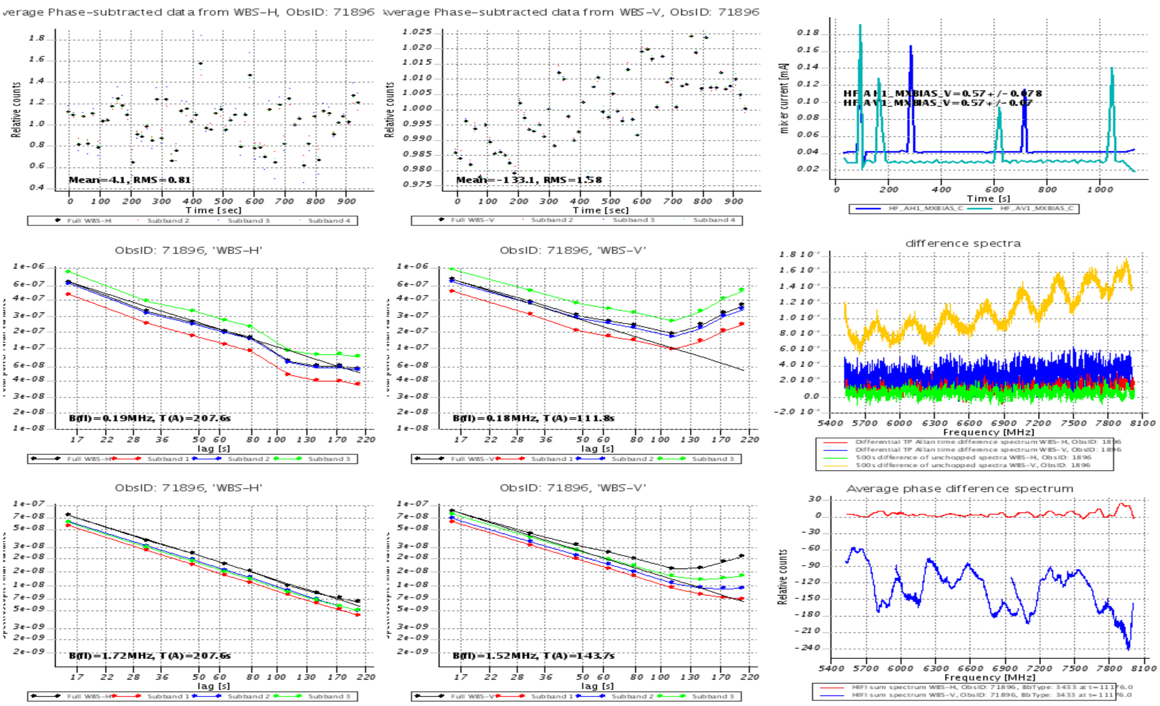


Fig. 118. B6b FSW for 900s. Throw 154 MHz. 500s baseline shows severe IF standing wave instability.

6.4.13 B7a Frequency switching (FSW), 1723 GHz.

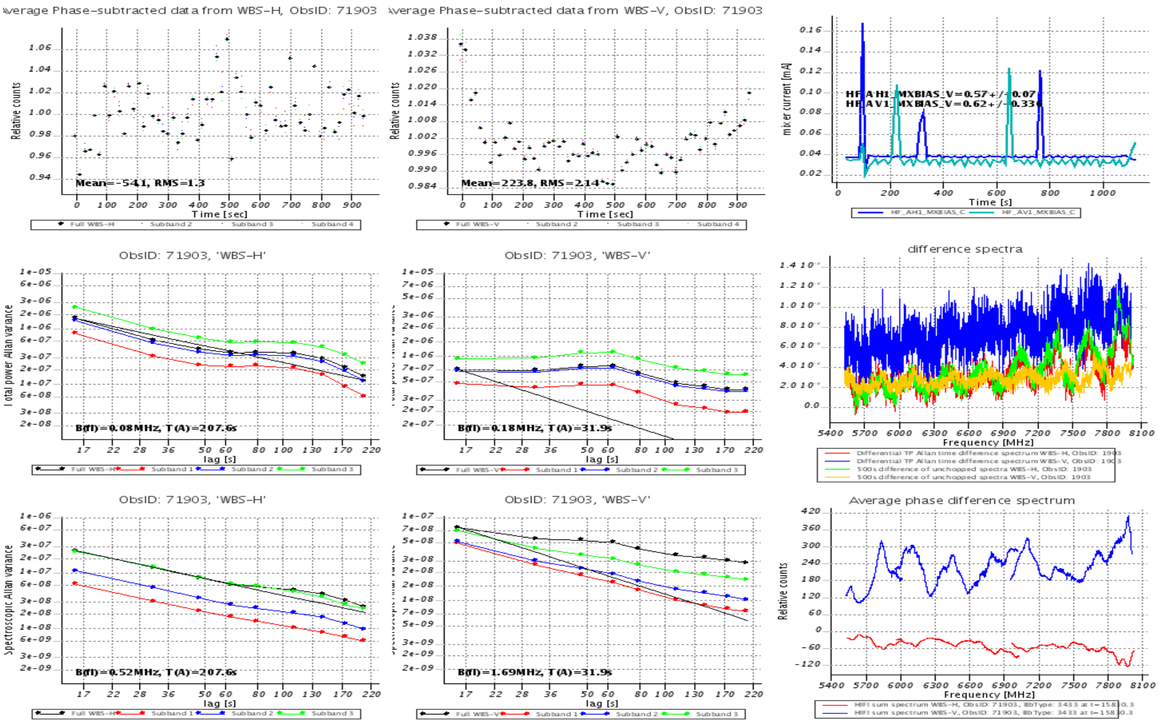


Fig. 119. B7a FSW for 900s. Throw 154 MHz. 500s baseline shows severe IF standing wave instability.

6.4.14 B7b Frequency switching (FSW), 1987 GHz, C+.

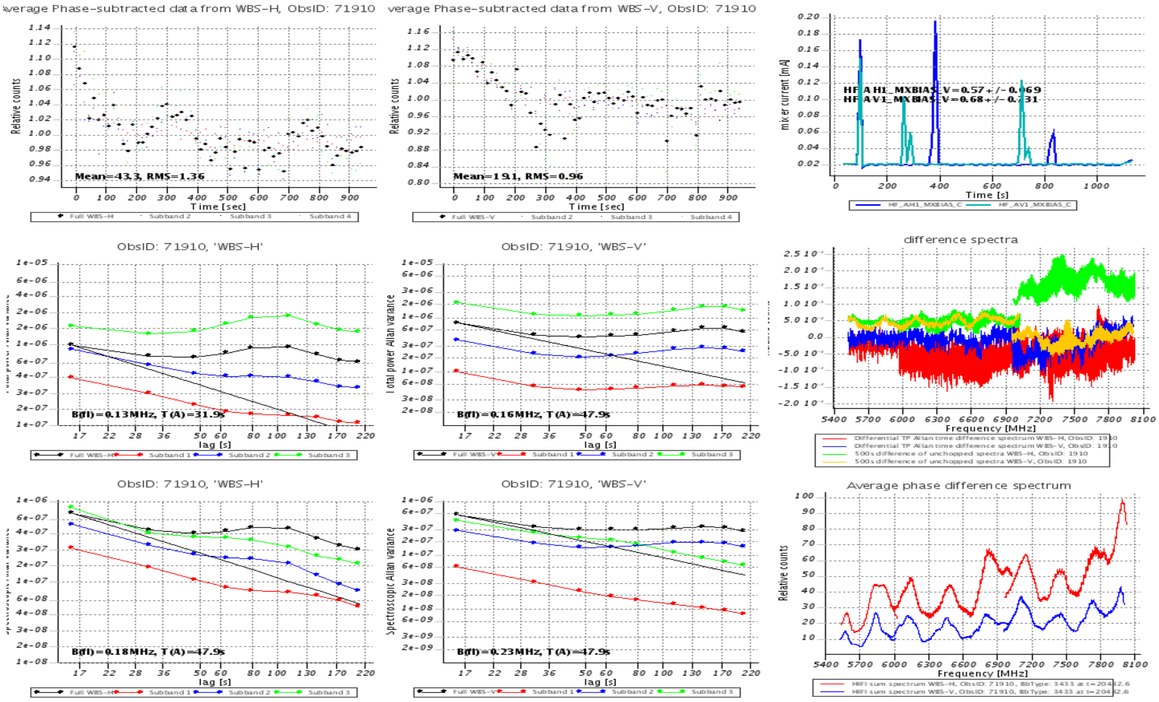


Fig. 120. C+, crap.

7 Parametric Stability tests

7.1 Stability as a function of Mixer Bias Voltage. (B5, B6-B7)

7.1.1 Objectives

Understand the effect of mixer bias voltage on the HIFI instrument total power stability.
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref].

7.1.2 Test Procedure

```
Configure instrument, nominal bias current, B-field, diplexer etc, stabilize if necessary
for mixer_band = 1, 5 do begin {
   select WBS/HRS low resolution mode
   for 2 different LO frequencies {          (2 stable, and two potentially unstable)
   select chopper internal Cold BB
     for Vsis= Vnom-0.1, Vnom, Vnom+0.1 {    (mV)
       adjust IF level
       perform WBS cal using the internal calibration source (zero-comb, RD20)
           for i = 0, 180 do {                  (6 minutes worth of TP data)
           acquire WBS spectrum {2sec}
           }
             select focal plane chopper, fast chop mode.
             adjust IF level
            perform WBS cal using the internal calibration source (zero-comb, RD20)
             for i = 0, 20 do {                 (Measure Y-factor, 20 seconds)
               select chopper internal Cold BB
               acquire WBS/HRS spectrum {1sec}
               select chopper internal Hot BB
               acquire WBS/HRS spectrum {1sec}
             }
     }
   }
}
end
```

CUS script name:

- *Testmode_Parameter_Scan_Investigation*
- *Testmode_Hotcold_w_stability (measure Y-factor)*

Note1: Total integration time 2 hours.
Note2: Symmetric chop on Y-factor measurement.
Housekeeping data should be acquired and stored throughout this and other test procedures.

7.1.3 Result

The total power Allan variance as a function of 3 bias voltages for 2 selected LO frequencies (stable, potentially unstable).

7.1.4 Discussion

In section 7.1 and 7.2 we investigate spectroscopic (system) stability as a function of mixer bias voltage. For the SIS mixers all parametric data was taken prior to the discovered need for optical attenuators [1-9]. Only B5 data is representative as no optical attenuation is needed.

In case of the SIS mixers, stability is expected to be a function of where the mixer is biased on the photon step since this changes the slope dP/dV. Thus a small variation in bias voltage results in a change in output power, and hence the potential for instability[15]. Since the width of the photon step is related to frequency (hf/e) we may expect, under the condition of fixed mixer bias, stability to also be a function of LO frequency. This is particularly the case in B5 where, due to the operation frequency being above the energy gap of the superconducting material (2D), the width of the photon step actually decreases with frequency. Adding to this Josephson oscillations (hf/2e) and it is evident that the selection of a proper bias point is important. Fig 121and Fig 122 below depict the mixer B5 stability as a function of bias voltage. In general reducing the B5 SIS mixer does not appear to affect the system stability. Increasing the mixer bias by 0.1mV however does. Mixer bias data tables obtained from P. Dieleman.

7.1.5 Vsis Band 5a

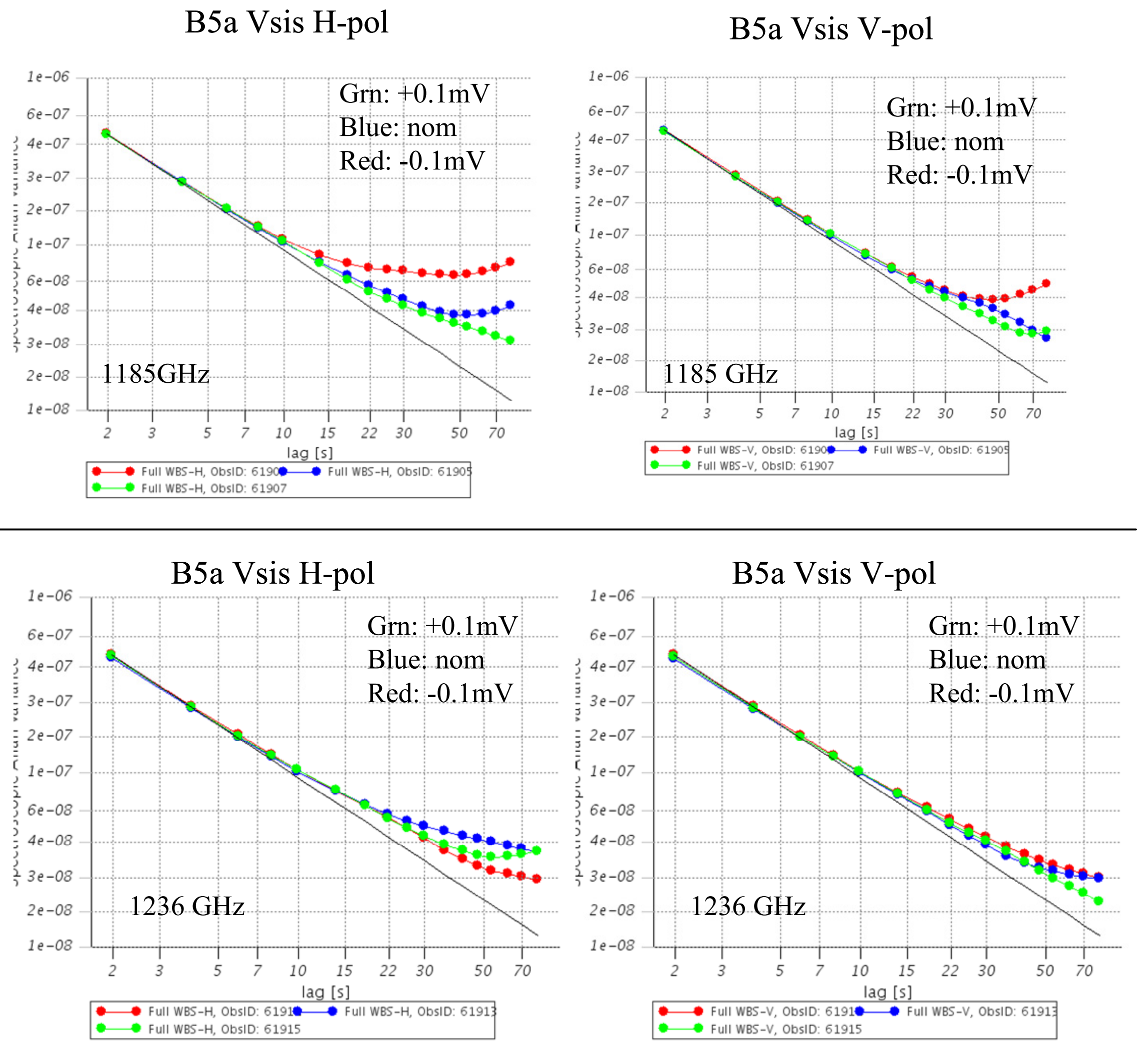


Fig. 121 B5a Spectroscopic system stability as a function of SIS bias voltage at 1185 GHz and 1236 GHz. 1236 GHz is just outside the official B5a LO operating range. Two frequencies at opposite end of the band were chosen based on LO bias vector scan extremes (Section 3). Increasing the mixer bias by 0.1mV is generally ok, decreasing is not.

7.1.6 Vsis Band 5b

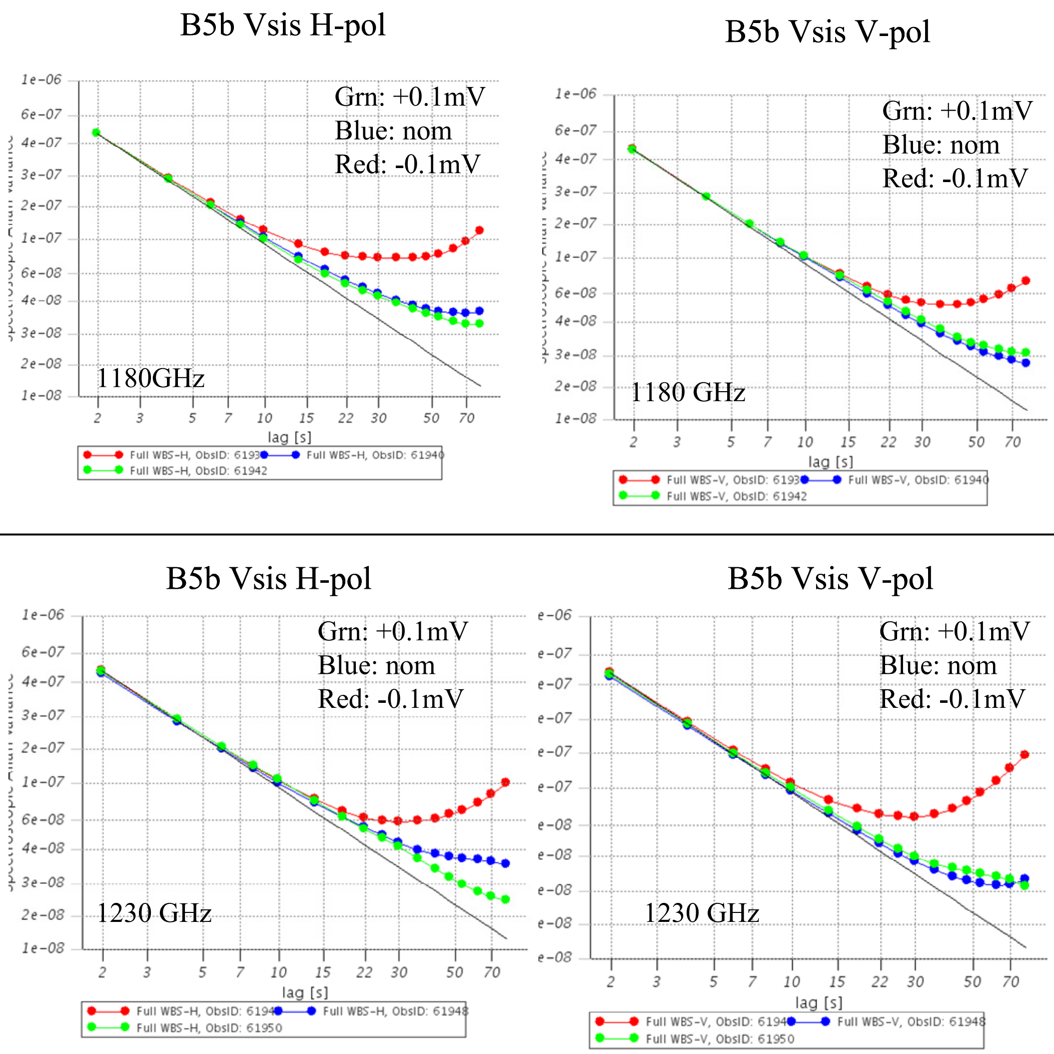


Fig. 122. B5b Spectroscopic system stability as a function of SIS bias voltage at 1180 and 1230 GHz. Result is consistent at both frequencies; increasing the B5 SIS bias by 0.1mV has no effect on the system stability, a decrease of 0.1mV does!

There are a wide variety of stimuli that affect the receiver stability. The bias voltage discussed here is just one of them. Evidence of (am) LO noise, microphonics, temperatures, and standing waves are presented in the preceding sections.

HEB mixers:
Generally speaking, when an HEB mixer is biased at a higher bias voltage, the distribution of the electron temperature in the center of the bridge increases as shown in Fig. 123. The curves correspond to a delicate heat-balance between energy input (dc bias and LO heating) and energy lost to electron-phonon interaction and cooling at the contact pads. Optimum sensitivity is achieved with a mixer bias of 0.4-0.6 mV [16]. If the mixer bias is increased to say 1 mV some sensitivity is lost, but stability is gained. This is depicted in Fig.'s 124-127.

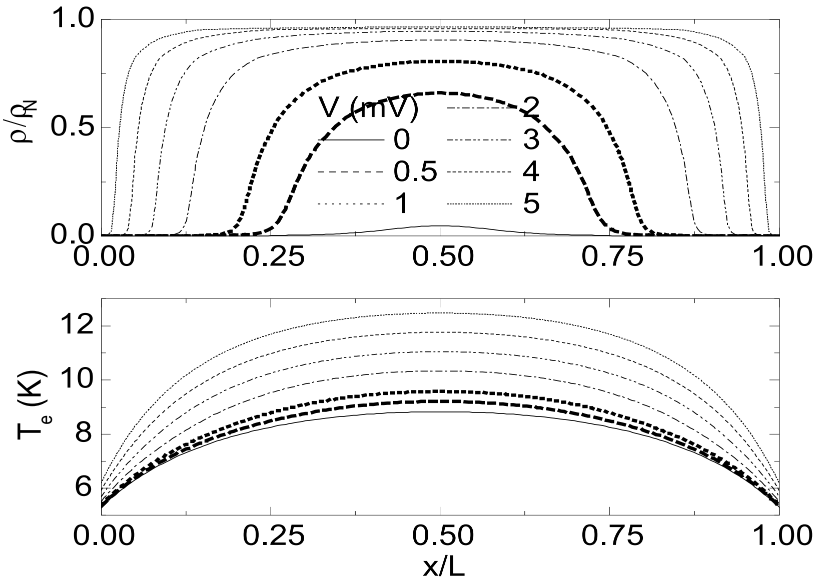


Fig. 123. Calculated normalized local resistivity (top) and temperature profile (bottom) of a Hot Electron Bolometer. The 0.5mV and 1.0 mV bias curves are highlighted. The device responds most strongly to bias changes around 0.5mV, as indicted by the normalized local resistivity curves. Source: Klapwijk *et al.* [17]

7.1.7 Vheb Band 6a

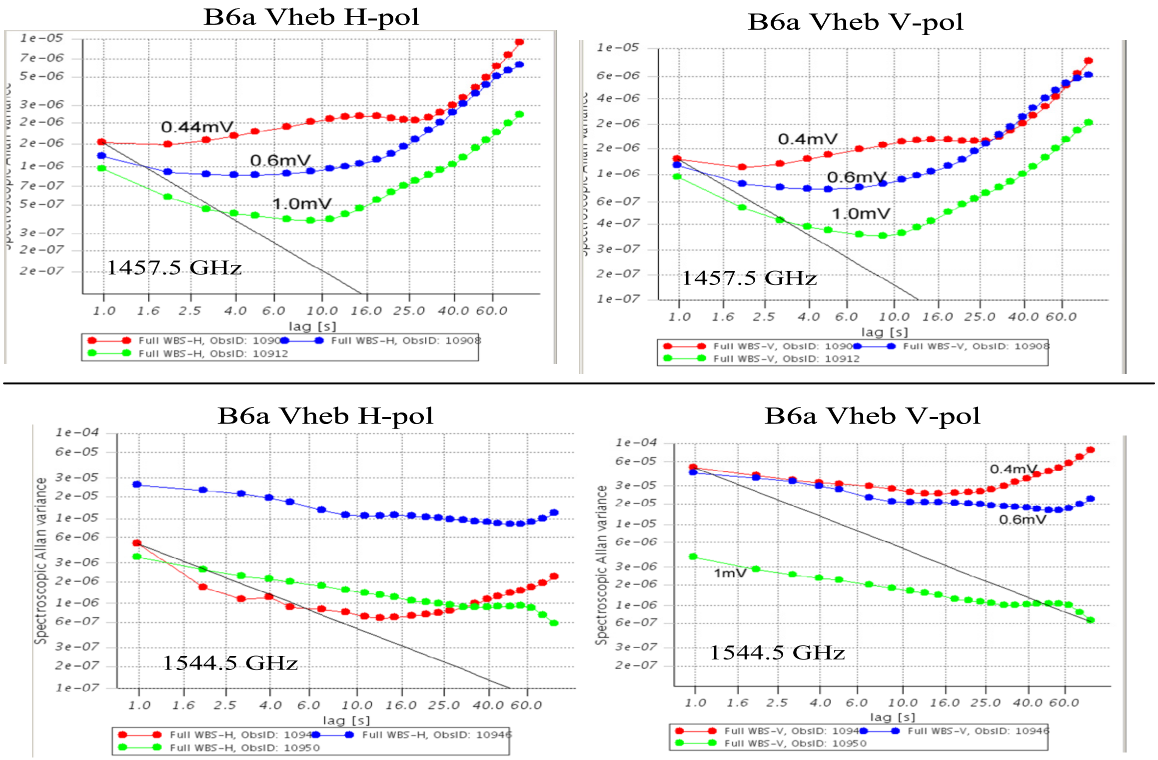


Fig. 124. B6a Spectroscopic system stability as a function of HEB bias voltage. Increasing the bias to 1mV does improve the stability somewhat. 1457.5 GHz (N II) is an unstable frequency and decreasing Tsys probably helps to minimize the effects of the local oscillator, standing waves, and microphonics.

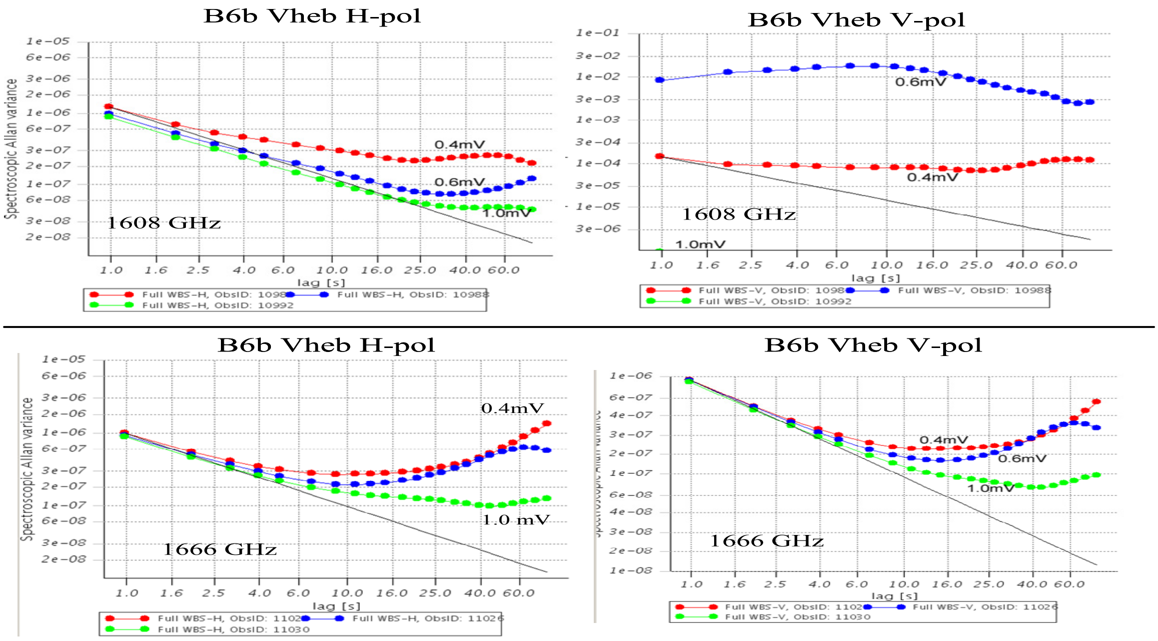


Fig. 125. B6b Spectroscopic system stability as a function of HEB bias voltage. Increasing the mixer bias to 1mV does help to stabilize the mixer response.

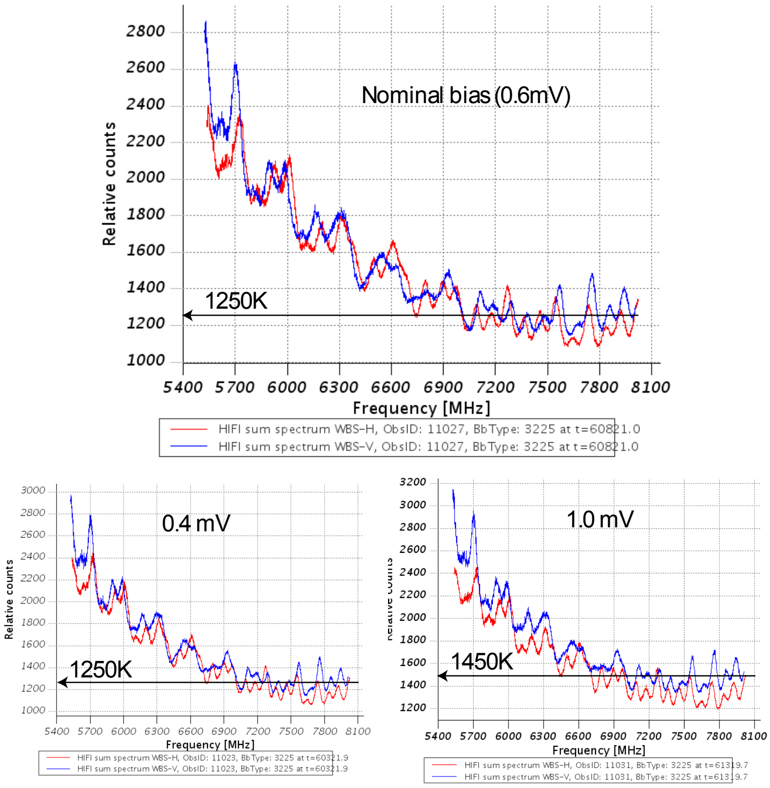


Fig. 126. B6b Tsys at 1666 GHz. It is clear that decreasing the bias does not affect Tsys consistent with our understanding (Fig 123), however increasing the bias to 1mV increases Tsys by 16%. **This may in some cases be a useful tradeoff in the event marginal stability prevents proper baselines.**

7.1.8 Vheb Band 7a

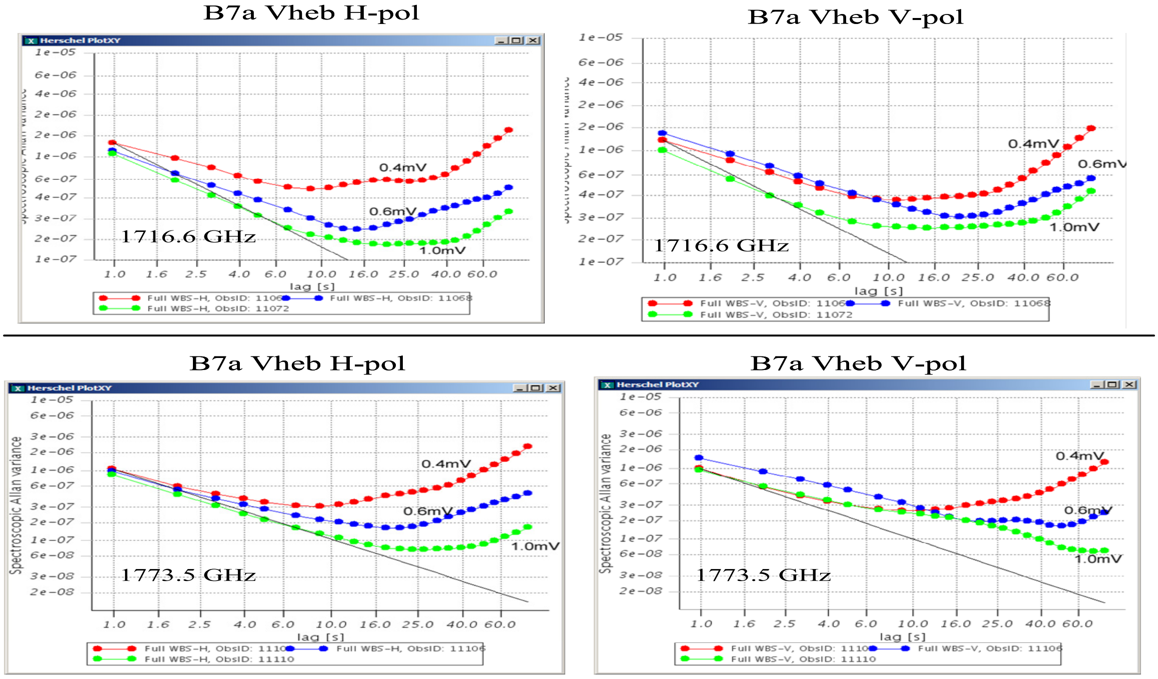


Fig. 127. B7a Spectroscopic system stability as a function of HEB bias voltage. Increasing the mixer bias to 1mV does help to stabilize the mixer response. For both plots Tsys|1mV is in error.

7.1.9 Vheb Band 7b

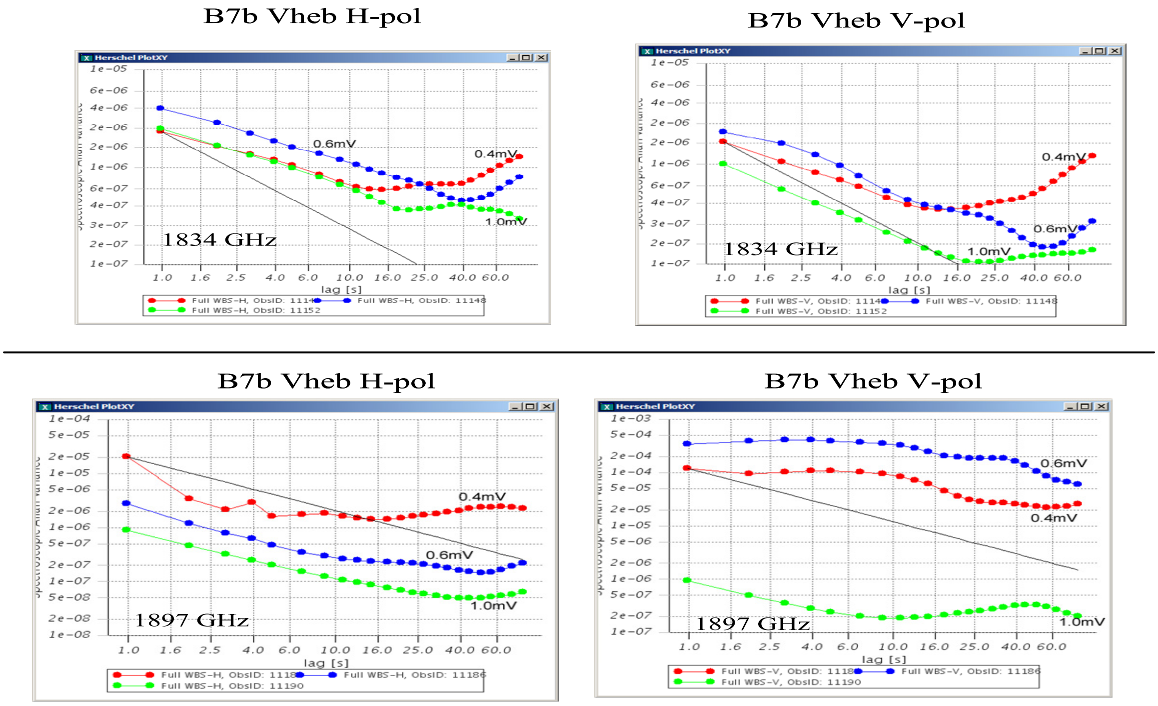


Fig. 128. B7b Spectroscopic system stability as a function of HEB bias voltage. Increasing the mixer bias to 1mV does help to stabilize the mixer response. For both plots Tsys|1mV is in error.

7.2 Stability as a function of Bias Current (change in Plo). (B6-B7)

7.2.1 Objectives

Understand the effect of mixer bias current on the HIFI instrument total power stability.
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref]..

7.2.2 Test Procedure

Configure instrument, nominal bias Voltage, B-field, diplexer etc, stabilize if necessary

```
for mixer_band = 1, 5 do begin {
    select WBS/HRS low resolution mode
    for 4 different LO frequencies {            (2 stable, and two potentially unstable)
    select chopper internal Cold BB
       for Isis= 30, 40, 50, 60{      (uA, change Vd JPL  Power Amps)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
             for i = 0, 180 do {                          (6 minutes worth of TP data)
             acquire WBS spectrum {2sec}
            }
                select focal plane chopper, fast chop mode.
             adjust IF level
             perform WBS cal using the internal calibration source (zero-comb, RD20)
                for i = 0, 20 do {                        (Measure Y-factor, 20 seconds)
                  select chopper internal Cold BB
                  acquire WBS/HRS spectrum {1sec}
                  select chopper internal Hot BB
                  acquire WBS/HRS spectrum {1sec}
                }
       }
   }
}
end
```

CUS script name:

- *Testmode_Parameter_Scan_Investigation*
- *Testmode_Hotcold_w_stability (measure Y-factor)*

Note1: Total integration time 1.5 hours/band
Note2: Symmetric chop on Y-factor measurement.
Housekeeping data should be acquired and stored throughout this and other test procedures.

7.2.3 Result

The total power Allan variance as a function of 4 bias currents for 2 selected LO frequencies (stable, potentially unstable).

7.2.4 Discussion

HEB mixers have a small operating range as far as bias voltage and LO pump level is concerned. This is because, as was seen in Fig. 123, due the to delicate thermal balance in the device. For the HIFI mixers the useable LO power ranges from approximately 30-60 uA (Iheb). In this case 60 uA corresponds to the least amount of LO pumping, beyond this the device goes unstable (Fig. 30, 33). As may be judged from Section 3, in many case a change from 30 to 60 uA corresponds to just a few bits (or less) on the ICU control voltage. Thus it is of interest to gain a feeling for the effect LO pump level has on the system stability.

7.2.5 Iheb Band 6a

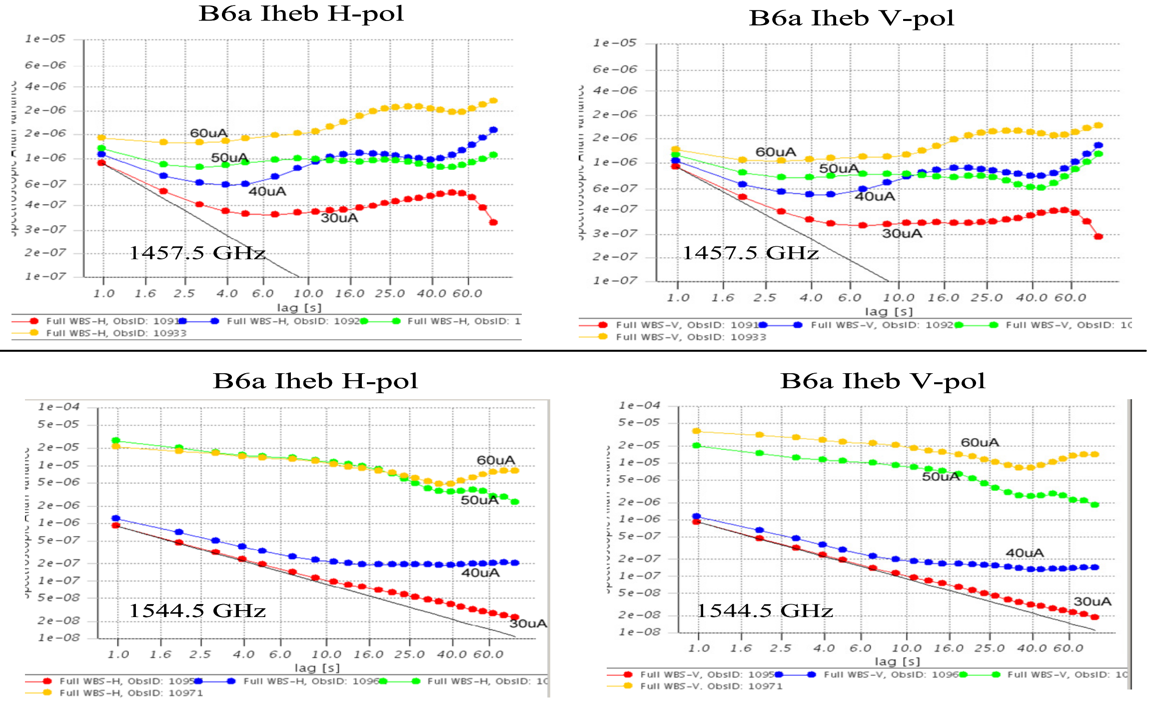


Fig. 129 B6a Spectroscopic system stability as a function of HEB bias current. Increasing the LO pump power (lower current) seems to be marginally better. 1457.5 GHz (N II) is an unstable frequency.

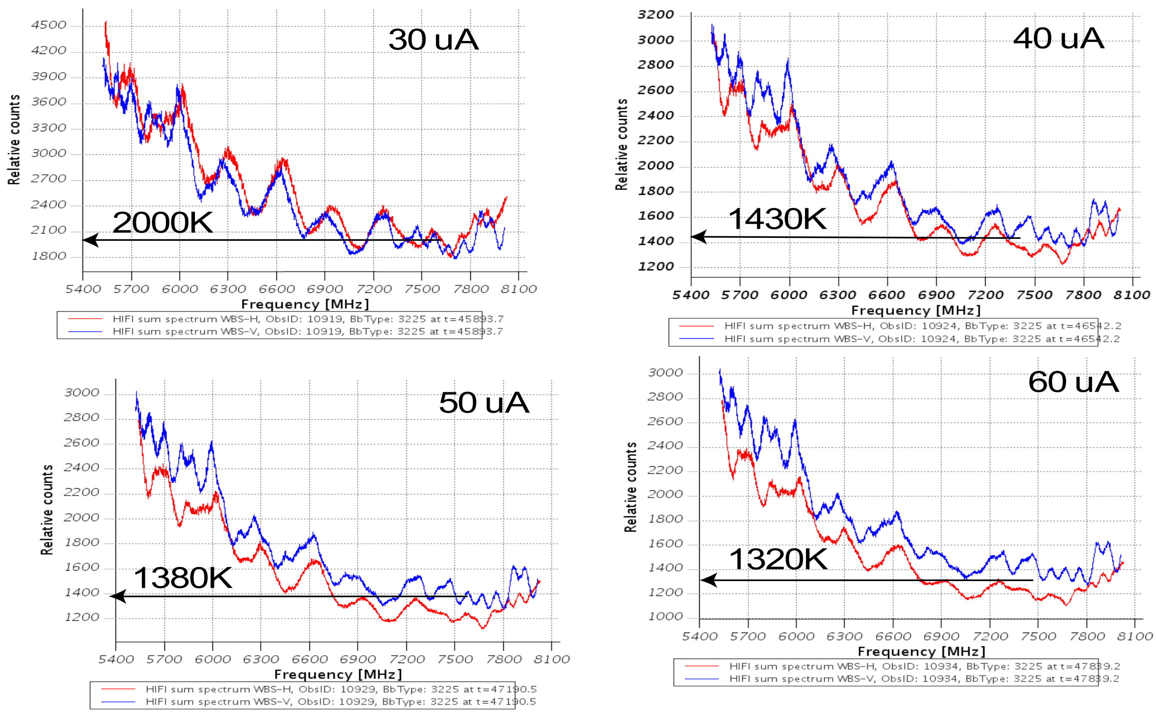


Fig. 130. B6a, 1457.5 (N II) Tsys. Over-pumping (30uA) is not good though the stability improves (See discussion Fig. 123). Under-pumping (60uA, less device heating) degrades the stability, however Tsys remains good. Optimal LO pump level is therefore 40-50 uA.

7.2.6 Iheb Band 6b

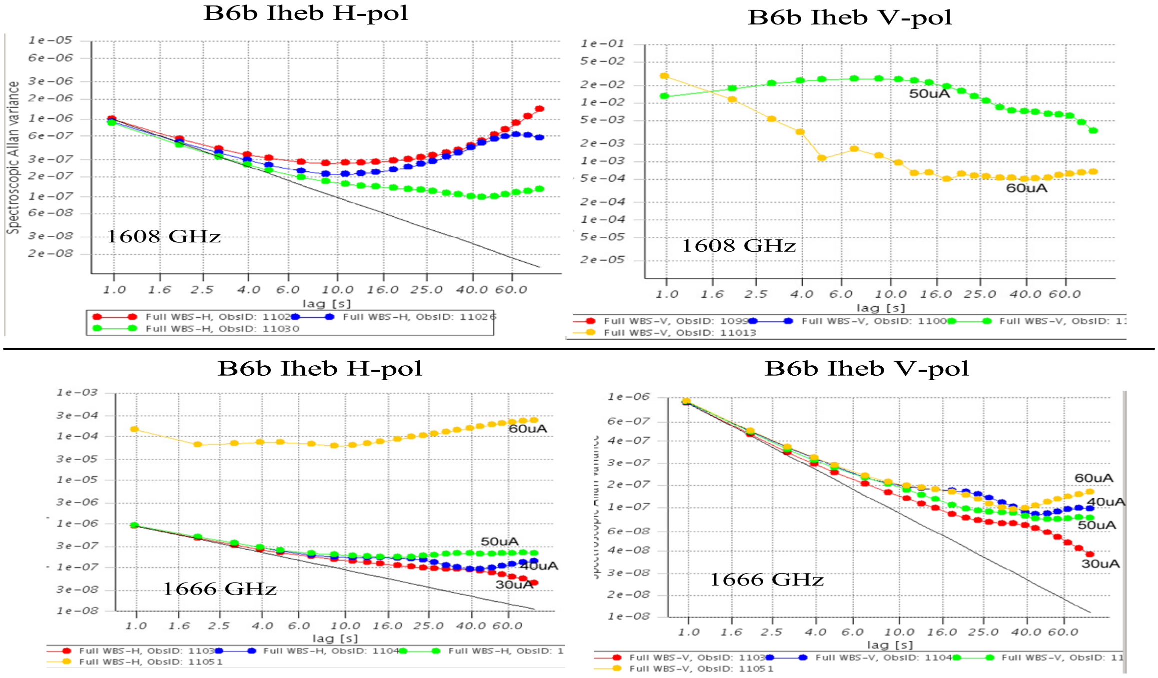


Fig. 131. B6b Spectroscopic system stability as a function of HEB bias current. 60 uA in this case caused the HEB to go unstable, affecting the plots. 1666GHZ V-pol 60 uA is just ok, and here we see a consistent behavior (over-pumping improves the stability, kills Tsys). Under-pumping (60uA) seems to be ok, until the 'cliff' is reached (H-pol).

7.2.7 Iheb Band 7a

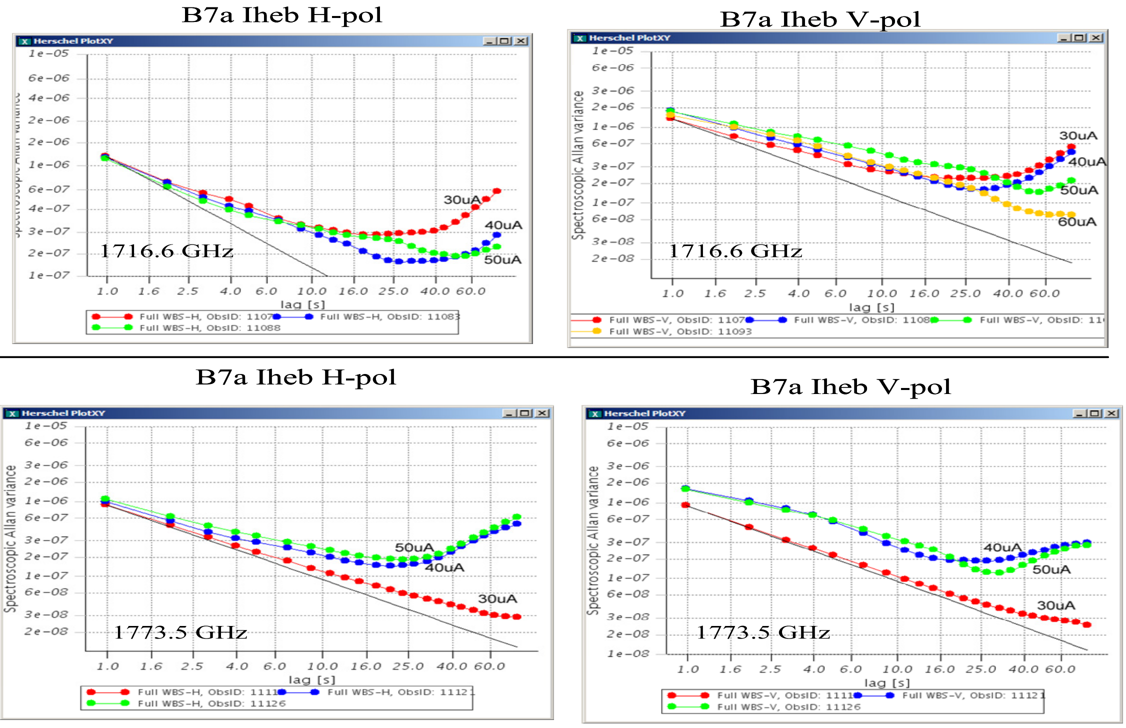


Fig. 132. B7a Spectroscopic system stability as a function of HEB bias current. Same result.

7.2.8 Iheb Band 7b

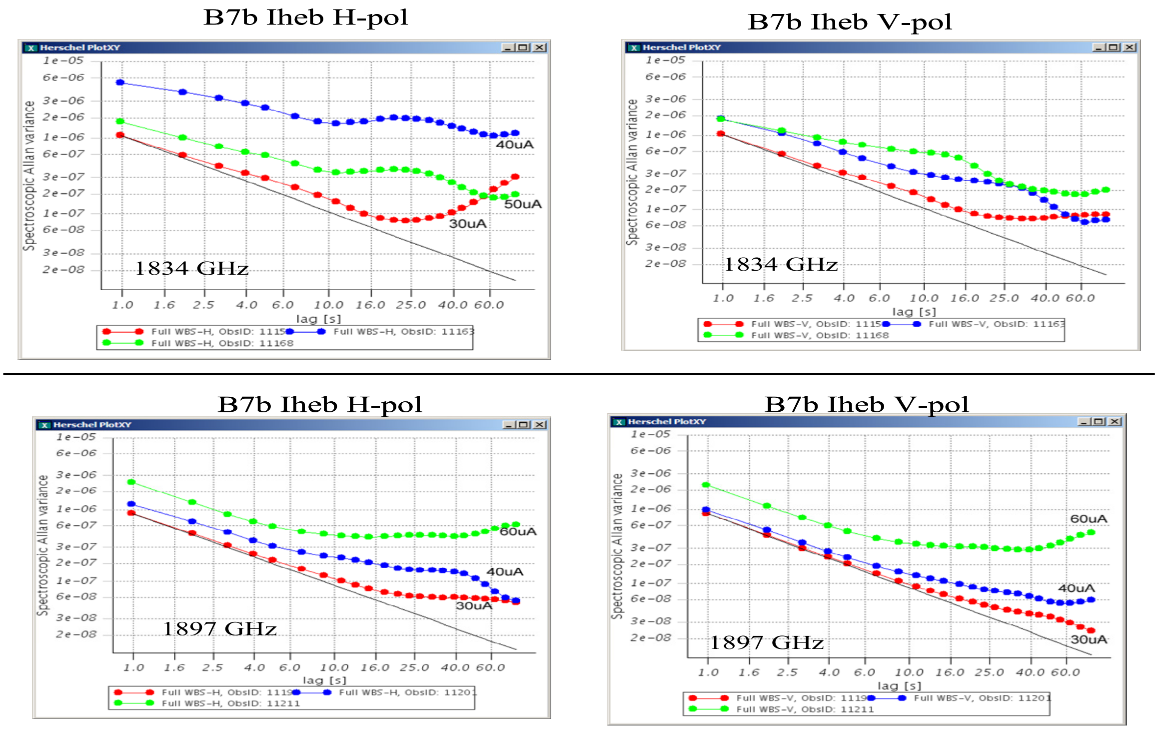


Fig. 133. B7b Spectroscopic system stability as a function of HEB bias current.

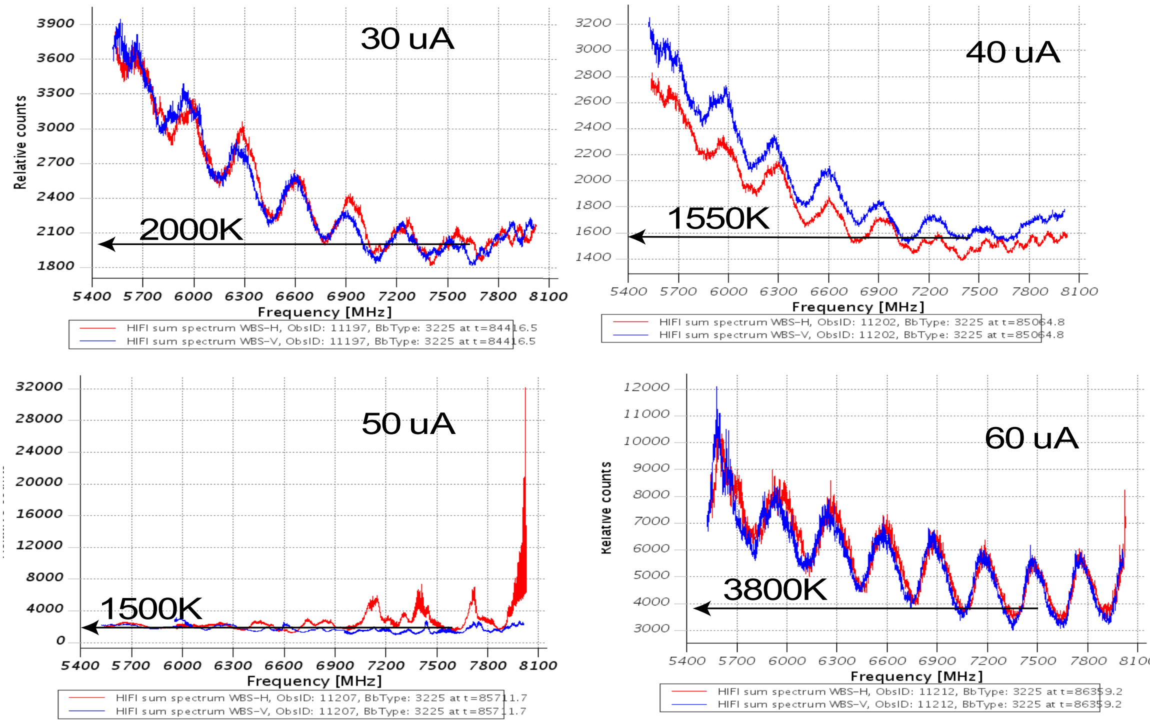


Fig 134.B7b 1898 GHz (C+) Tsys. Too much LO-power (30 uA) increase the stability performance, but also degrades Tsys (30%), consistent with theory. Under-pumping (60uA) results in increased instability and a large IF reflection [18]. The 40-50uA range provides expected results.

7.3 Stability as a function of B-field. (B5)*

7.3.1 Objectives

Understand the effect of mixer B-field on the HIFI instrument total power stability.
Determine the influence of the environment (i.e. temperature) on instrument stability [Ref].

7.3.2 Test Procedure (B1-B5)

Configure instrument, nominal bias, nominal B-field, diplexer etc, stabilize if necessary

```
for mixer_band = 1, 5 do begin {
    select WBS/HRS low resolution mode
    for 4 different LO frequencies {          (2 stable, and two potentially unstable)
    select chopper internal Cold BB
       for Bfield= Bfield-6%, Bfield+0%, Bfield+6%,{    (mA)
        adjust IF level
        perform WBS cal using the internal calibration source (zero-comb, RD20)
             for i = 0, 180 do {                     (6 minutes worth of TP data)
             acquire WBS spectrum {2sec}
            }
                select focal plane chopper, fast chop mode.
              adjust IF level
              perform WBS cal using the internal calibration source (zero-comb, RD20)
                for i = 0, 20 do {                   (Measure Y-factor, 20 seconds)
                  select chopper internal Cold BB
                  acquire WBS/HRS spectrum {1sec}
                  select chopper internal Hot BB
                  acquire WBS/HRS spectrum {1sec}
               }
       }
    }
}
end
```

<u>**CUS script name:**</u>

- *Testmode_Parameter_Scan_Investigation*
- *Testmode_Hotcold_w_stability (measure Y-factor)*

Note1: Total integration time 2 hours.
Note2: Symmetric chop on Y-factor measurement.
Housekeeping data should be acquired and stored throughout this and other test procedures.

7.3.3 Result

The Allan variance as a function of 3 B-field currents for 42selected LO frequencies (stable, potentially unstable).

* B1-B4 were taken before insertion of Optical attenuation. Data considered non-representative.

7.3.4 Discussion

SIS mixers exhibit excess noise when Cooper pairs are broken. This is known as the Josephson effect. It happens at discrete frequencies, hf/2e. Josephson noise can be squelched by 1 flux quantum, however to set the appropriate amount of flux (Bfield) usually requires a bit of trial and error. Unfortunately, much of the parametric stability data was taken before the insertion of the optical attenuators, and so only B5 data is available for analyses.

7.3.5 B-field B5a

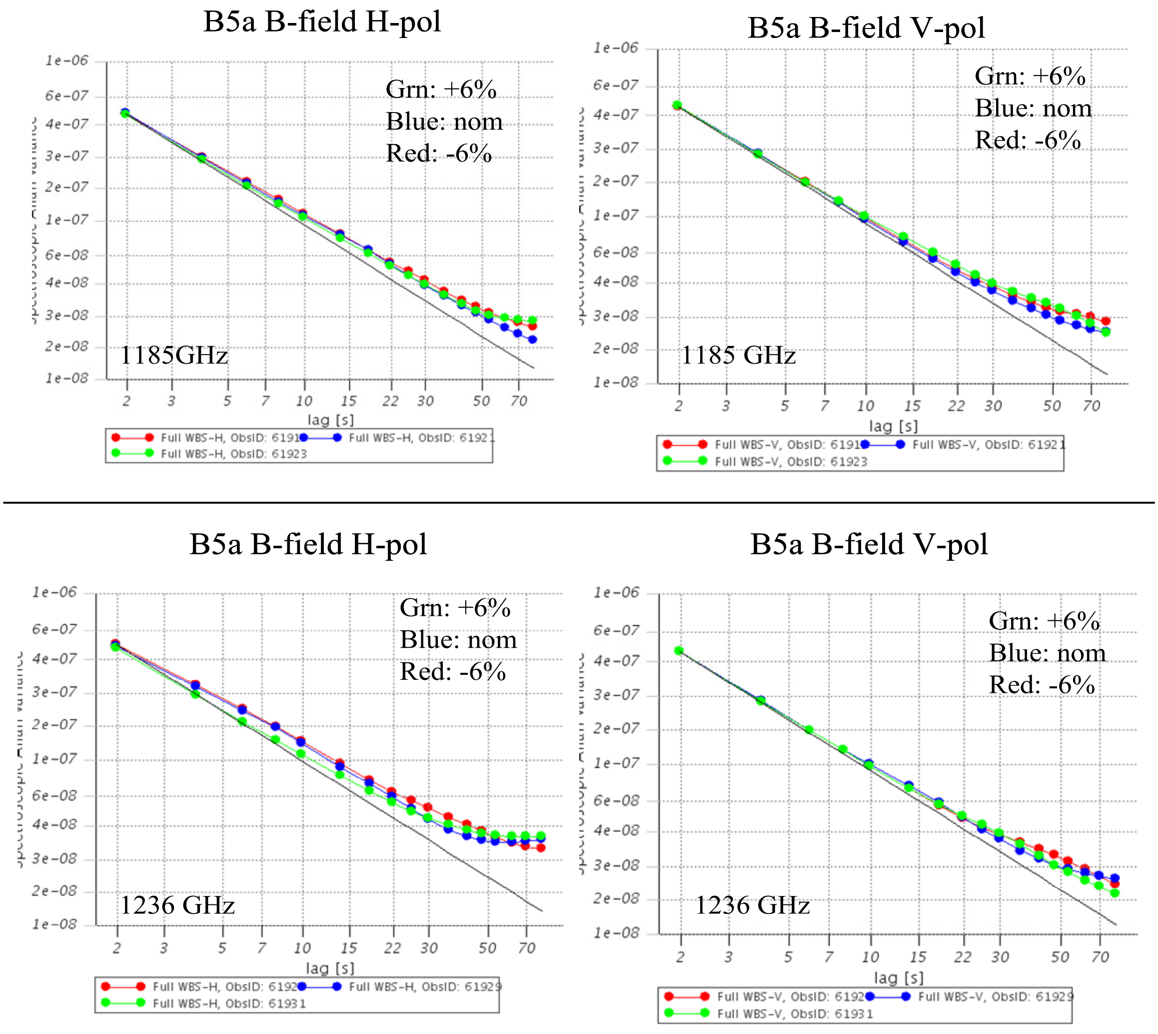


Fig. 135. B5a Spectroscopic system stability as a function of magnetic field. It is apparent that B-field changes on the order of +-6% from nominal is acceptable.

7.3.6 B-field B5b

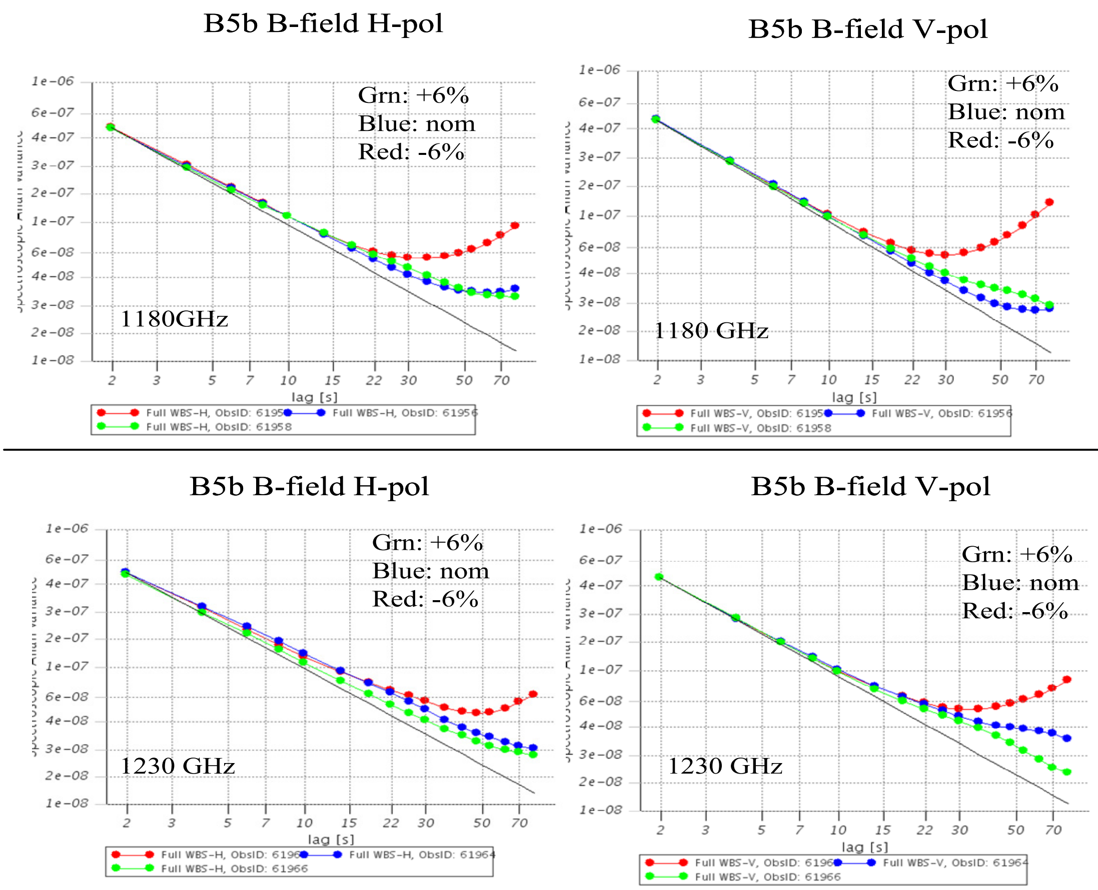


Fig. 136. B5b Spectroscopic system stability as a function of magnetic field. Here we see a consistent degradation in stability with a reduction in applied magnetic field. Most likely the 'nominal' setting was not quite centered, unlike it was the case for B5a in Fig. 135.

8 Conclusion

We have measured the HIFI instrument stability (ILT). The use of optical attenuators, to force the local oscillators into a more stable regime, has proven critical. In general we find the system stability acceptable for the SIS bands and marginal for the HEB mixer bands. Though not completely unexpected, what did come as a surprise is the level of instability in HEB mixer band 7b. We make some recommendations in this regard at the end of the conclusion.

Stability for all mixer bands is dominated by the individual LO sub-bands, and as such the HIFI instrument really ought to be thought of as 14 individual receiving units. This result has had a considerably impact on the required test time during ILT, and data reduction/analyses time. It will undoubtedly impact the thermal vacuum (TV) and performance verification (PV) planning as well.

There is for each LO sub-band, with the exception of B5, a considerable spread in Allan stability time. For a large part we attribute this to excess LO noise. There is however also the effect of compressor induced vibrations in the FPU - LOU standing wave cavity. Especially at the higher frequencies (B6, B7) this is expected to have some effect. To this effect, TV and PV measurements will be very important, and adequate test time should be render to all bands, but in particular bands 6 and 7.

Frequency switching is an important observing mode, however due to time pressure it has been for a large part omitted from the ILT. In Section 6.4 we show results from a preliminary set of tests. The results are very encouraging for the SIS bands, but seriously questionable for the HEB mixer bands. HEB mixers are thermal devices, and even a minute change in LO power, e.g. change in the LO-mixer standing wave, will upset the equilibrium and effect the baseline subtraction.

As discussed, mixer band 7b has some serious instability problems everywhere except at the band edges. In part this may be related to how hard the LO power amplifier and multiplier chain is being driven. There is however also an issue with spectral purity at the 1898 GHz (USB) C+ line. Last minute tests with an external (VDI) signal source revealed that by biasing the first multiplier (M1) more negative resolved the issue. The presented stability data in this report were all taken with the more positive 'incorrect' M1 bias. It is unlikely that a change in M1 bias affects the overall stability of B7b since the spectral purity problem is relates to a parametric oscillation/interaction with the multiplier bias circuit. In fact with the more positive 'incorrect' M1 bias we measure good stability at 1898 GHz (band edge). Thus the poor stability and parametric oscillation are probably two separate issues. It is recommended therefore that special attention be given to B7b during TV. In addition, a dedicated investigation of stability issues with the spare B7b LO chain would be very useful.

Finally, the presented results, in ascii format, have been forwarded to the ICC team to be integrated into HSPOT.

9 Acknowledgments

We like to thank John Pearson, John Ward, Robert Lin at the jet Propulsion laboratory (JPL), Thomas Klein, Christian Leinz, Gundolf Wieching, Rolf Gueston at the Max Planck Institute for Radio-astronomy (MPIfr) for LO related input/advice, Willem Luinge for coordinating the ILT tests, including setting aside the needed (~200hours) test time, Nick Whyborn and Peter Dieleman for their input in system related issues, Klaas Wildeman and Robert Huisman for grid, and miscellaneous HIFI optics discussions, Willem Jellema for his help in sorting out the multitude of encountered beam and optical attenuator problems, Heino Smit for assistance with the electronics and removal of the numerous round loops, Hans Golstein for his expertise in IF/EMI related matters, Jaap Evers for answering the many detailed quality control questions, Ronald Hesper for making available his FTS and general insight, The machine shop for making last minute hardware changes, Jurgen Stutzki and Frank Schmulling at the University of Koeln (KOSMA) for making available the 'hifi@koeln' machine, on which much of the data was reduced, Xander Tielens for providing the list of HIFI's 'most important' line frequencies, David Teyssier for all his help with CUS scripts, vector scans (and the like), Rob de Haan and Norbert Bruning for running the many scripts and providing feedback on the run status of the hundreds of obsid's, Kees Wafelbakker for supporting the large amount of time required in light of a very tight schedule, and Tom Phillips, Thijs de Graauw for making it all possible.

10 References

1) HIFI_Instabilities_MPIfR110407.pdf, R. Guesten with the LO S/S team, 06 April, 2007.

2) HIFI_LOStability_investigations23April2007.pdf, J. Kooi, J. Pearson, T. Klein, C. Leinz, G. Wieshing, 23 April 2007.

3) 070503-FM-band6-7instability investigation_1_0.pdf, C. Leinz, J. Ward, M. Caris, 02 may. 2007

4) HIFI_Stability_investigations_kooi08May2007.pdf, J. Kooi, J. Pearson, R. Lin, J. Ward, T. Klein, C. Leinz, G. Wieshing, 08 May 2007.

5) HIFI_Stability_investigations3_kooi16May2007.pdf, J. Kooi, J. Pearson, R. Lin, J. Ward, T. Klein, C. Leinz, G. Wieshing, 16 May 2007.

6) Development status quasi-optical attenuators for HIFI, draft 1.0, W. Jellema, 22 April 2007, LO attenuator budget, draft 1.1, W. Jellema, 3 October 2007

7) Design presentation HIFI LOU/FPU baffle, 25 June 2007, Groningen, HIFI LO Frequency Coverage and Hot-Cold Survey Results, HIFI SRAG Meeting, 25 June 2007, Groningen

8) Stability_testsJan152007v3.pdf, J. Kooi, V. Ossenkopf, Jan 15, 2007.

9) IF2_feedback_compared.pdf, J. Kooi, V. Ossenkopf, M. Olberg, O. Siebertz, Mar. 24, 2007.

10) Ossenkopf V., 2003, „A unified Allan variance computation scheme", ICC/2003-013, 07/31/03

11) Ossenkopf V., 2004, „Optimisation of mapping modes for heterodyne instruments, test report, 03/10/04

12) Ossenkopf V., 2005, „On the spectroscopic baseline instability observed in the QM and DM-II ILT“, technical report, 05/12/05

13) Ossenkopf V., 2003, ``Analysis of the differential stability measurements on the HIFI DM in May 2004", test report, 07/16/2004

14) Schieder R., Kramer C. 2001, „Optimisation of heterodyne observations using Allan variance measurements“, A&A 373, 746

15) Noise Stability of SIS Receivers, J.W. Kooi, G. Chattopadhyay, M. Thielman, T.G. Phillips, and R. Schieder, Int. J. IR and MM Waves,, Vol. 21, No. 5, May, (2000).

16) Stability of Heterodyne Terahertz Receivers, J.W. Kooi, J.J.A. Baselmans, A. Baryshev, R. Schieder, M. Hajenius, J.R. Gao, T.M. Klapwijk, B. Voronov, and G. Gol'tsman, Journal of Applied Physics, Vol. 100, 064904, Sep. (2006).

17) Improved superconducting hot-electron bolometer devices for the THz range, T. M. Klapwijk, R. Barends, J. R. Gao, M. Hajenius, and J. J. A. Baselmans, in Proc. of SPIE, vol. 5498: Millimeter and Submillimeter Detectors for Astronomy II, edited by J. Zmuidzinas, W. S. Holland, and S. Withington, (Glasgow, Scotland, UK 2004), pp. 129.

18) IF Impedance and Mixer Gain of NbN Hot-Electron Bolometers, J. W. Kooi, J. J. A. Baselmans, J. R. Gao, T. M. Klapwijk, M. Hajenius, P. Dieleman, A. Baryshev, and G. de Lange, Journal of Applied Physics, Vol. 101, 044511, Feb. (2007).