Characterisation of the TELIS Autocorrelator Spectrometer

P. Vogt*, M. Birk*, G. Wagner*, F. Geiger*, G. de Lange†, H. Golstein†, O. Kiselev†, A. Emrich‡

*Remote Sensing Technology Institute, DLR
E-Mail: Peter.Vogt@dlr.de

†SRON
E-Mail: G.de.Lange@sron.nl

‡Omnisys Instruments AB
E-Mail: ae@omnisys.se

Introduction

Radiometric accuracy, as for every spectrometer, is vital for the balloon-borne heterodyne receiver TELIS[1] in order to obtain radiometric calibrated and corrected spectra.
Gas cell measurements have been performed to investigate the radiometric properties of the whole system. However, the results showed unexpected errors which dominate the radiometric accuracy.
A more detailed error analysis method is required to be able to localise, quantifiy and (if possible) correct the observed errors.

TELIS Autocorrelator

- 1.5 bit autocorrelator spectrometer from Omnysis[3]
- I-Q-sampling technique
- 500 MHz sampling rate
- input signal downconversion to four segments:
  1.8-3.8GHz → 4x 0.5GHz

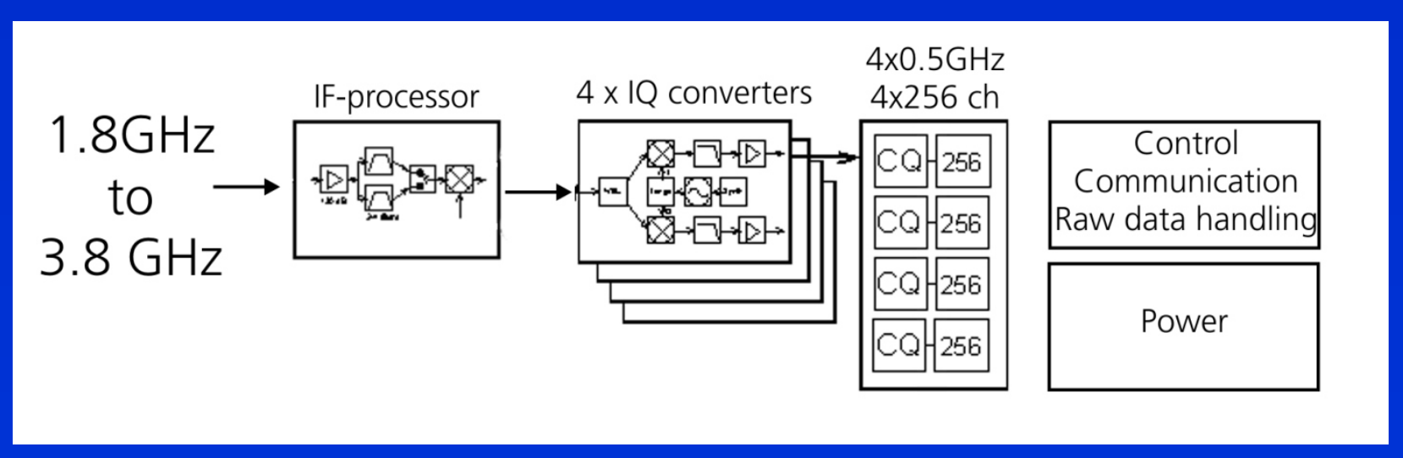

Fig.1: Autocorrelator system draft (simplified)

Gas Cell Measurements

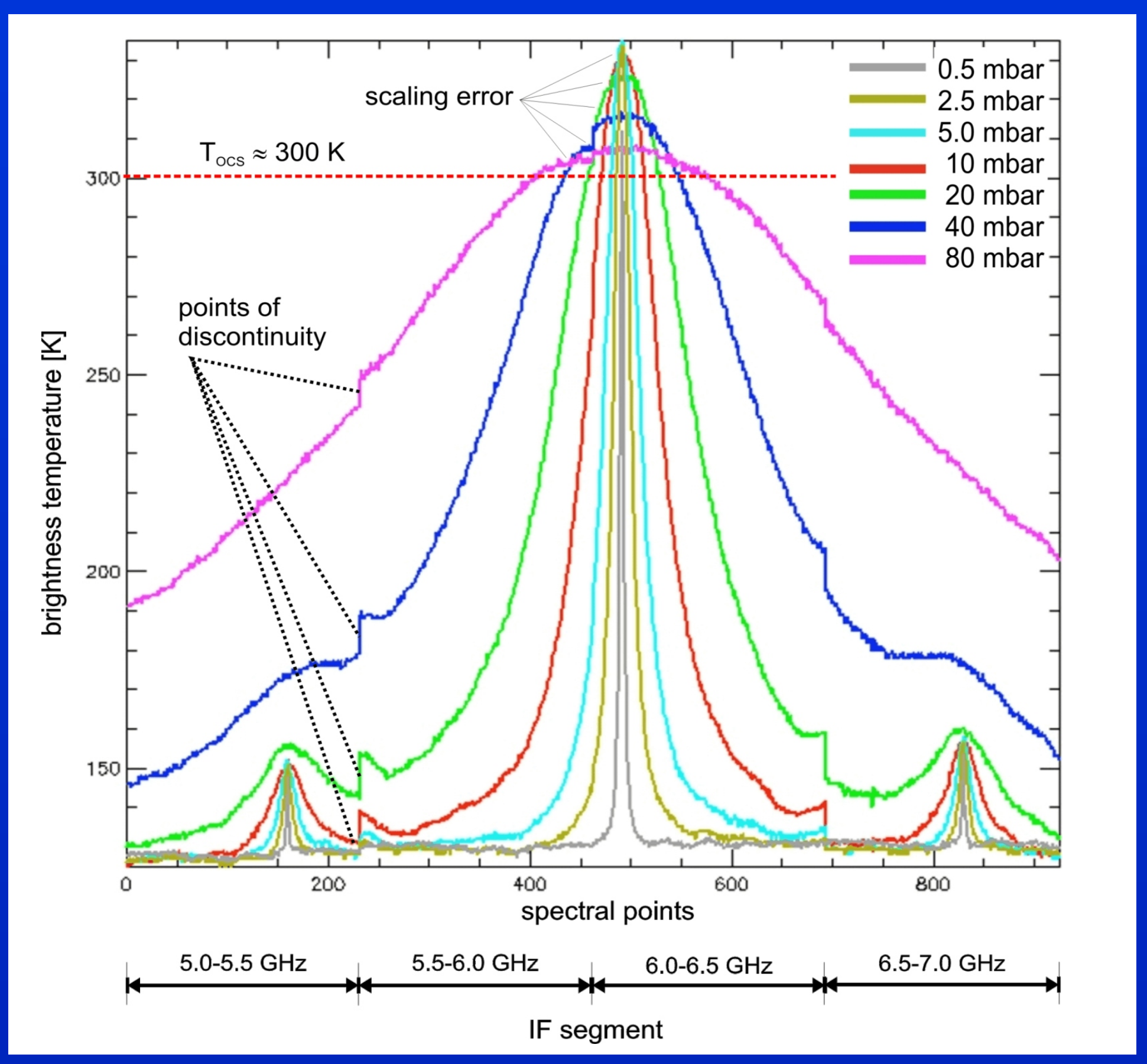

Fig.2: Calibrated spectra of opaque OCS-lines superimposed of both sidebands at different gas pressures

Observed errors:

- atmospheric signal too large by up to 20 %
- scaling error depends on linewidth
- linewidth dependent discontinuities at junctions of all four spectral segments of the autocorrelator

Simultaneous fits of all measurements with common baseline and individual spectroscopic parameters were made.
Scaling and offset parameters needed to be introduced to be able to compensate the observed errors (table1) :

IF segment	p[mb]	scaling factor	offset [K]
5.0 - 5.5 GHz	2.5	0.843	-
	5	0.860	-
	10	0.871	-
	20	0.915	-
	40	0.984	-
	80	1.041	-8.2
5.5-6.0 GHz	2.5	0.793	-1.25
	5	0.842	-0.96
	10	0.854	0.16
	20	0.862	0.81
	40	0.879	2.69
	80	0.952	-3.33

Table1: Correction parameters for calibrated spectra of OCS with respect to pressure and IF-segment

The IF-segment dependence of the correction factors implies an spectrometer error.
A more detailed spectrometer characterisation is required...

New Characterisation Approach

Intercomparison of the TELIS autocorrelator spectrometer (ACS) with a well-characterised Fast Fourier Transform spectrometer (FFTS)[2]:

- Simultaneous measurements of an adjustable signal source with both spectrometers
- (SIG-REF)/REF measurements for line shape and scaling error analysis
- Calibrated spectra measurements for brightness temperature offset analysis

Signal Source

Broadband noise source + synthesizer line

Broadband source:

- amplified noise signal of 50Ω resistor
- flat in frequency
- noise power: $P_\Omega \sim k_B T \Delta f$
- T controlled with slush bath

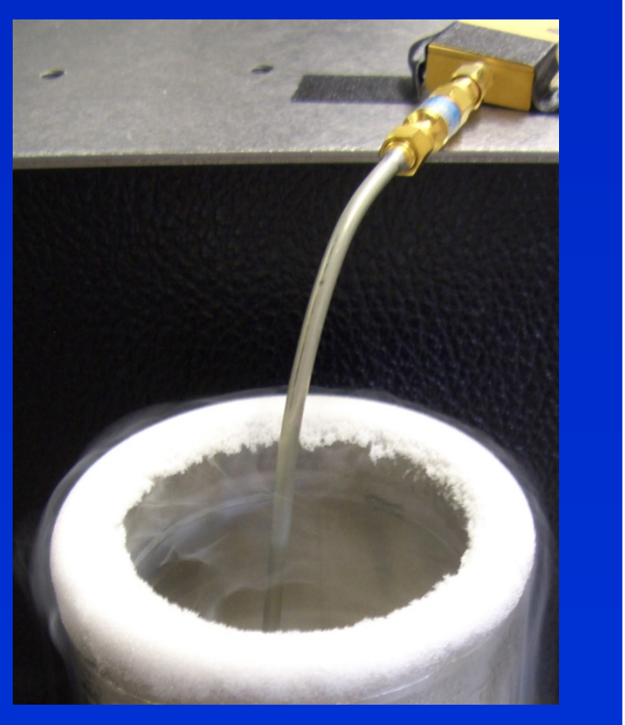

Fig.3: Slush bath

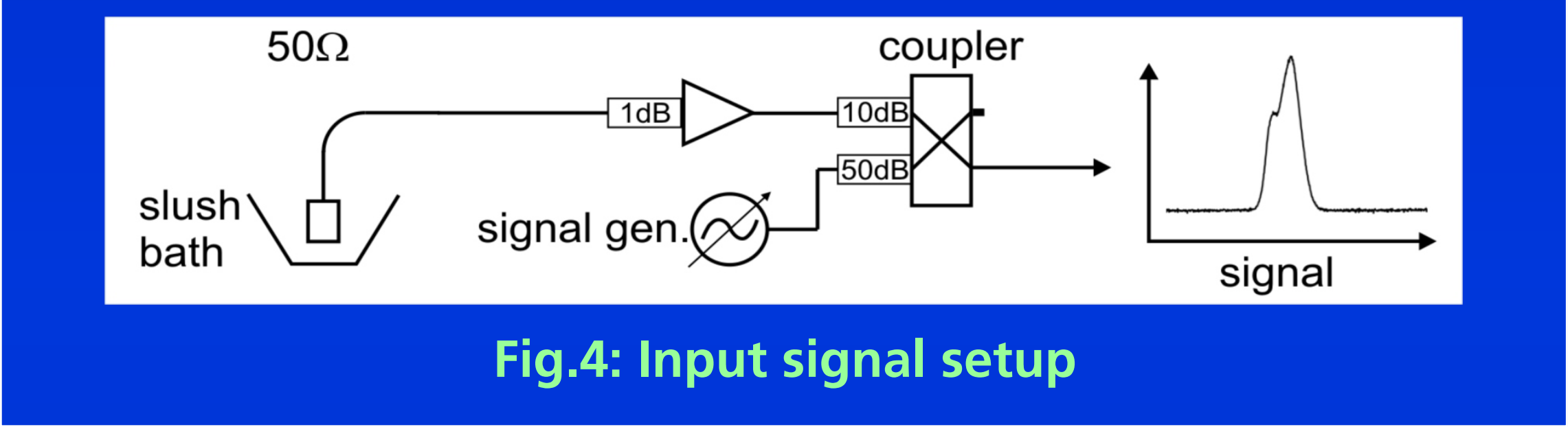

Fig.4: Input signal setup

Spectrometer Setup

ACS specifications:

resolution: Δf=2.5 MHz
input range: 1.8 to 3.8 GHz
integration time: T = 1.5 s

FFTS specifications:

resolution: Δf=0.212 MHz
input range: 0.1 to 1.5 GHz
integration time: T = 1.5 s

Measurement Setup:

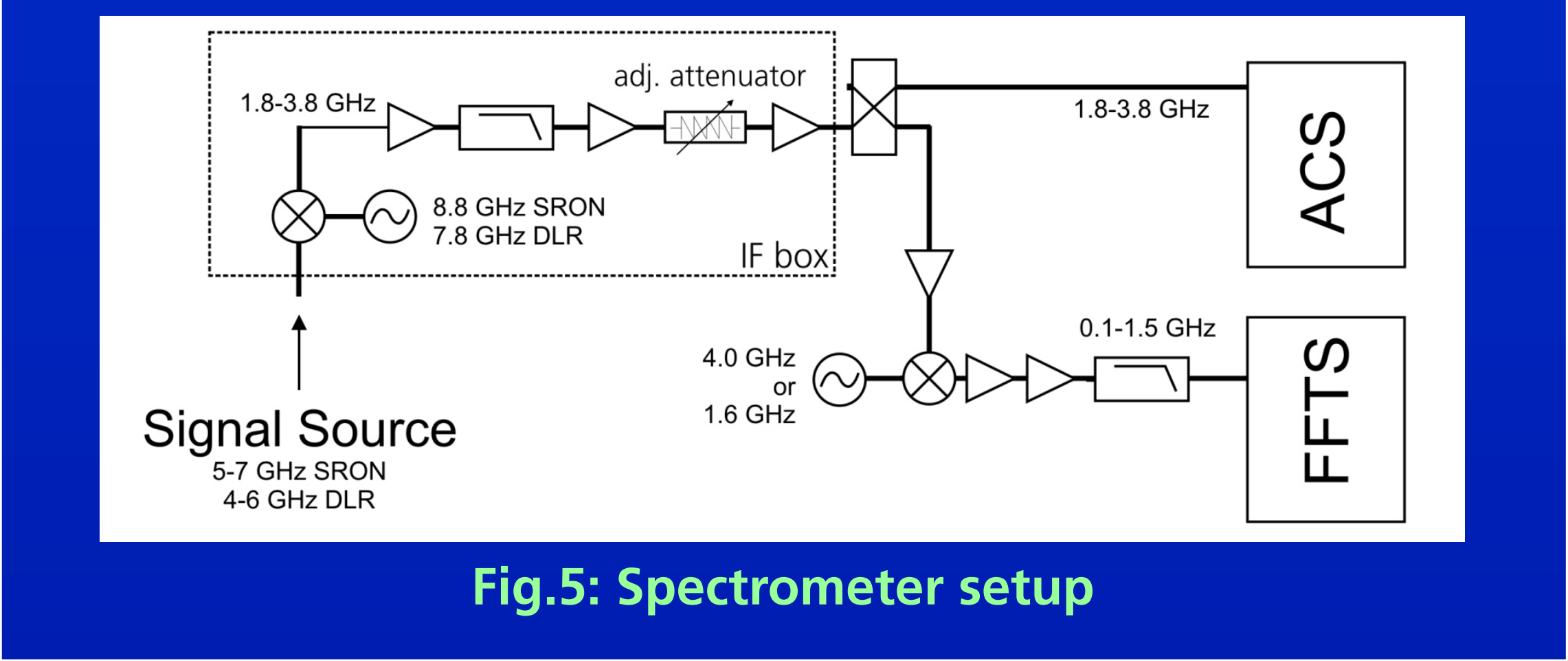

Fig.5: Spectrometer setup

Measurement Concept

- Signal source is set at 24 different line frequencies to cover full spectral range of 2 GHz
- Signal power level is adjusted in attenuator steps of 4dB, 8dB and 12dB
- Calibration measurements used as hot and cold load are recorded from 273K and 77K slush baths
- Line signals and reference signals are recorded from 200K slush bath
- Slush temperatures are measured with calibrated temperature sensor
- Autocorrelator temperature is stabilised with water cooling to eliminate long term drifts

First Results

Temperature offset evaluation:

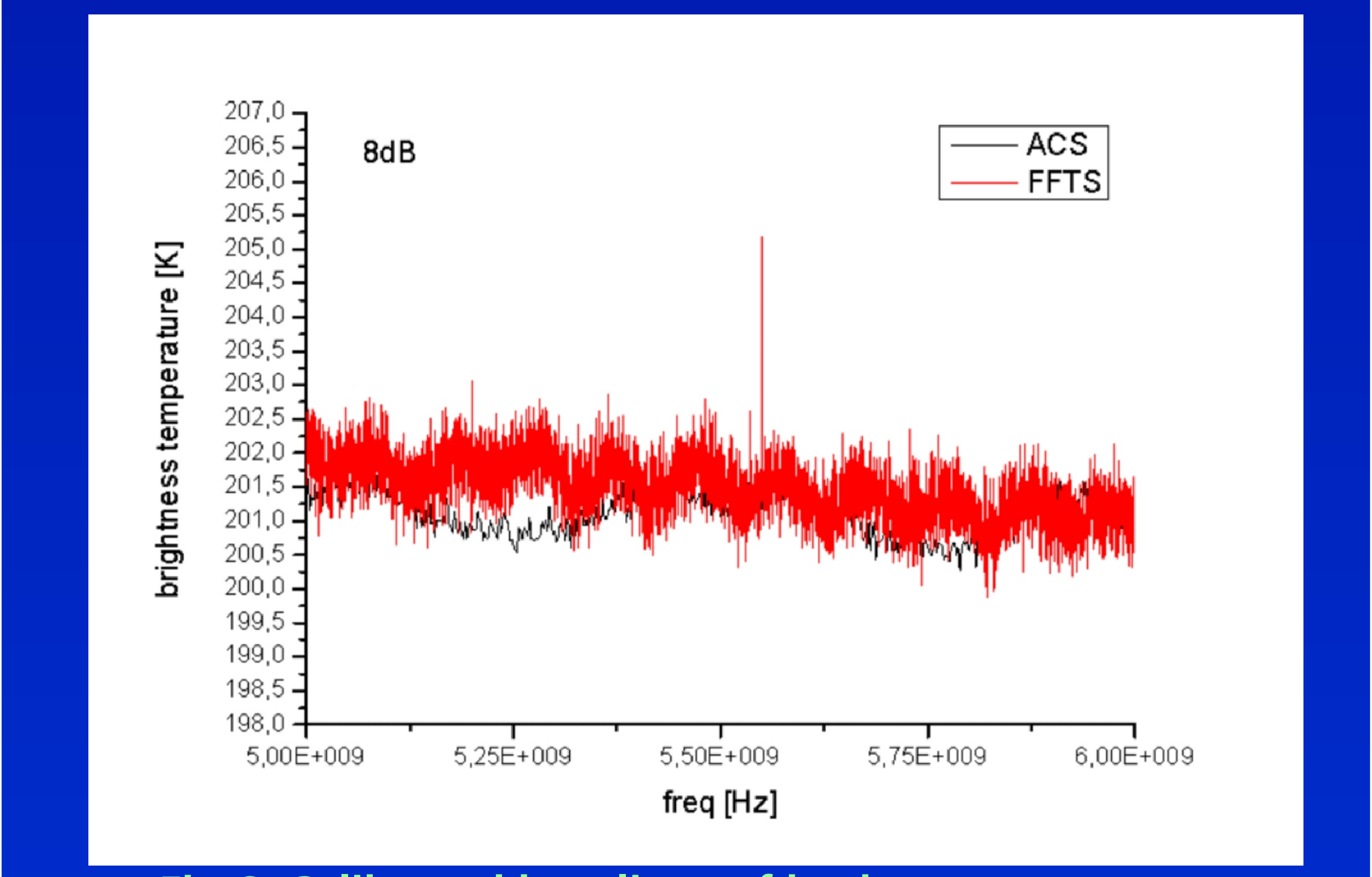

Fig.6: Calibrated baselines of both spectrometers, attenuator 8dB, T_{slush} = 200.3 K

Average brightness temperatures compared to measured slush temperatures as a function of attenuator setting:

attenuator	$\langle T_{acs}\rangle$ [K]	$\langle T_{ffts}\rangle$ [K]	$\langle T_{acs}\rangle - T_{slush}$ [K]	$\langle T_{ffts}\rangle - T_{slush}$ [K]
4dB	203.0±0.44	205.5±0.86	2.9±0.44	5.4±0.86
8dB	201.1±0.31	201.5±0.46	0.8±0.31	1.2±0.46
12dB	200.0±0.29	199.9±0.56	0.0±0.29	-0.1±0.56

Table2: Temperature offsets of ACS and FFTS

A non-linearity of about 1.5% for the ACS and 2.7% for the FFTS setup with respect to the 200K calibration point was measured.

Linescaling intercomparison:

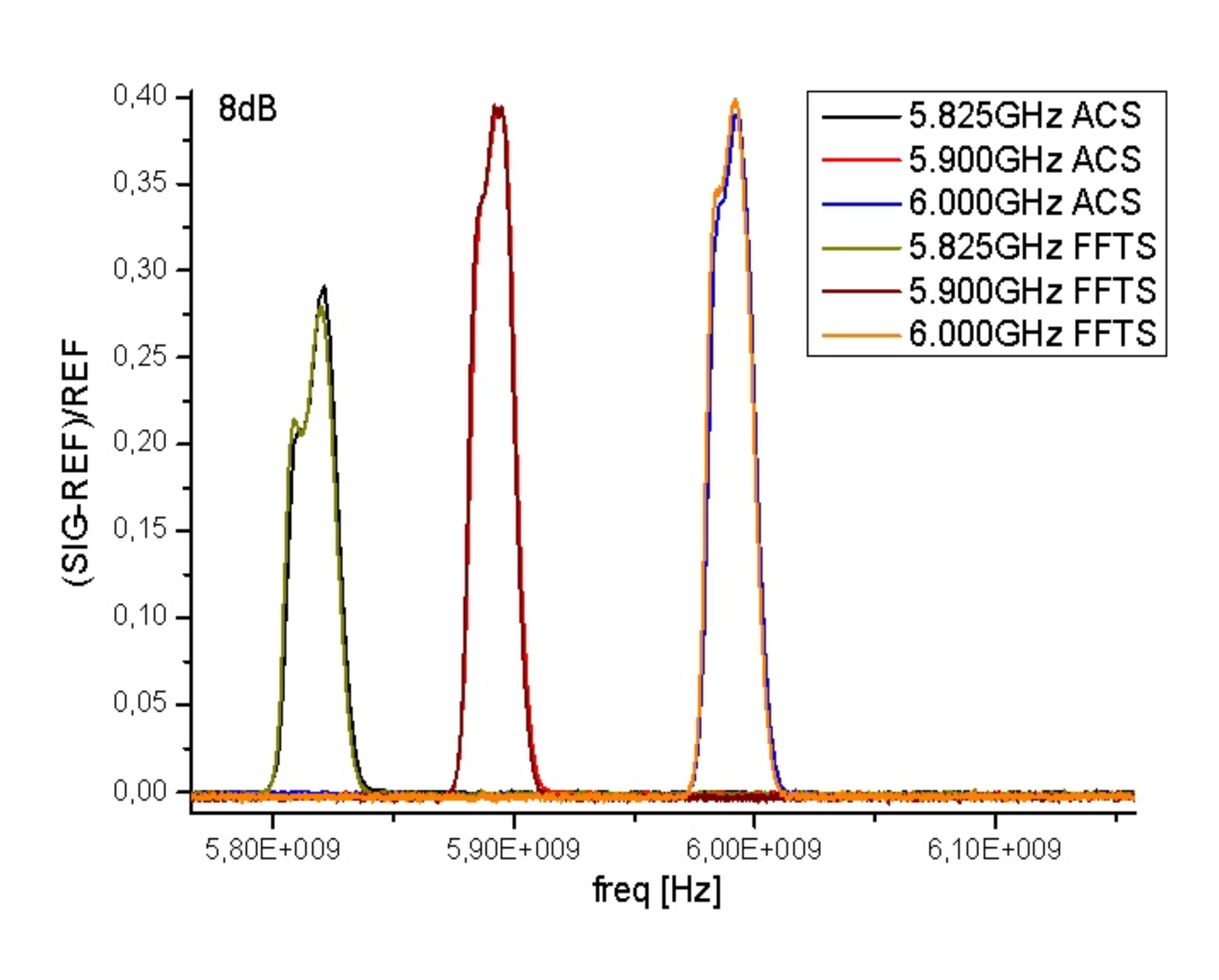

Fig.7: Detail of synthesizer lines measured

Results:

- Area integration under corresponding lines is used to determine scaling factors between both spectrometers.
  The factors range from 0.96 to 1.02 for ACS over FFTS (5.0 GHz to 6.0 GHz segment).
- Scaling error at 6 GHz line is less than 1%
- Different line intensities and attenuator settings show no major effect on relative scaling of ACS and FFTS
- Good agreement of ACS and FFTS lineshapes, however, crosstalk can be observed for some lines in the ACS spectra

Conclusion and Outlook

Results so far indicate no autocorrelator error in the order of magnitude as observed in the OCS measurements.
This is however in contradiction to gas cell measurements which required IF-segment and hence autocorrelator specific correction parameters.
Further gas cell investigation need to be carried out, also with FFTS.

---

[1] 'TELIS: TErahertz and subMMW LImb Sounder - Project Summary After First Successful Flight', M. Birk, G. Wagner, G. de Lange, A. de Lange, B.N. Ellison, M.R. Harman, A. Murk, H. Oelhaf, G. Maucher and C. Sartorius, 21st International Symposium on Space Terahertz Technology, Oxford, 23-25 March 2010

[2] 'Fast Fourier Transform Spectrometer', B. Klein, I. Krämer, S. Hochgürtel, R. Güsten, A. Bell, K. Meyer, and V. Chetik, 20th International Symposium on Space Terahertz Technology, Charlottesville, 20-22 April 2009

[3] Omnisys Instruments AB

DLR
Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft