The SHFI receiver and APEX backends

Central slot
In Nasmyth
Cabin A

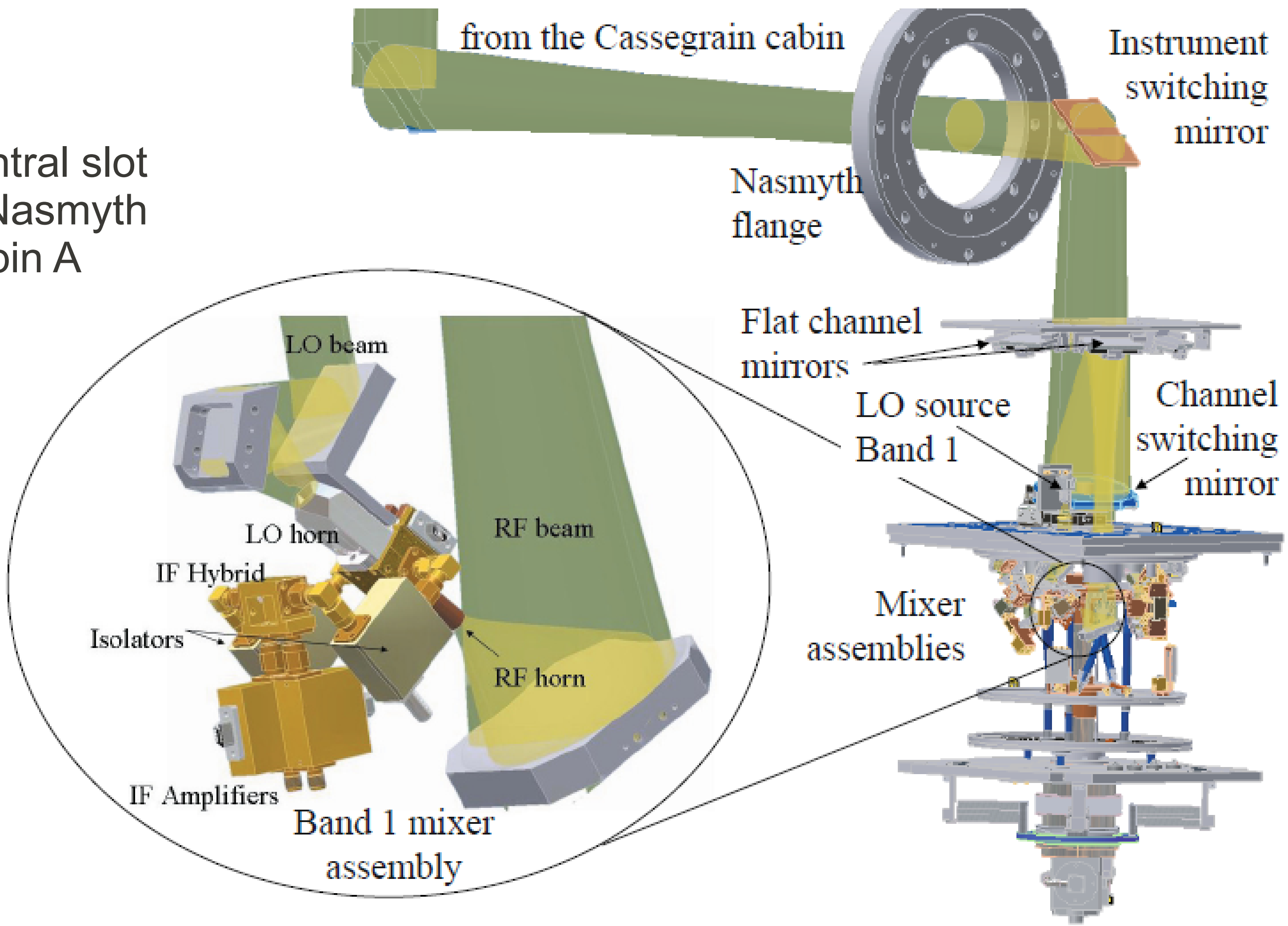

Fig. 1. Structure of the SHFI cryostat.

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A Swedish heterodyne facility instrument for the APEX telescope

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ABSTRACT

Aims. In March 2008, the APEX facility instrument was installed on the telescope at the site of Lliano Chajnantor in northern Chile. The main objective of the paper is to introduce the new instrument to the radio astronomical community. It describes the hardware configuration and presents some initial results from the on-sky commissioning.
Methods. The heterodyne instrument covers frequencies between 211 GHz and 1390 GHz divided into four bands. The first three bands are sideband-separating mixers operating in a single sideband mode and based on superconductor-insulator-superconductor (SIS) tunnel junctions. The fourth band is a hot-electron bolometer, waveguide balanced mixer. All bands are integrated in a closed-cycle temperature-stabilized cryostat and are cooled to 4 K.
Results. We present results from noise temperature, sideband separation ratios, beam, and stability measurements performed on the telescope as a part of the receiver technical commissioning. Examples of broad extragalactic lines are also included.

Key words. telescopes – instrumentation: detectors – techniques: spectroscopic – radio lines: general

Instrument	Type	Mode	Frequency [GHz]	HPBW [arcsec]	IF range [GHz]	# of beams	Location	Status
APEX-1 (SHeFI)	Heterodyne SIS	SSB	214 - 275	30 - 25	4 - 8	1	Nasmyth-A	✔
APEX-2 (SHeFI)	Heterodyne SIS	SSB	267 - 378	23 - 17	4 - 8	1	Nasmyth-A	✔
APEX-3 (SHeFI)	Heterodyne SIS	DSB	385 - 500	17 - 13	4 - 8	1	Nasmyth-A	✔
APEX-T2 (SHeFI)	Heterodyne HEB	DSB	1250 - 1390	5	2 - 4	1	Nasmyth-A	✖

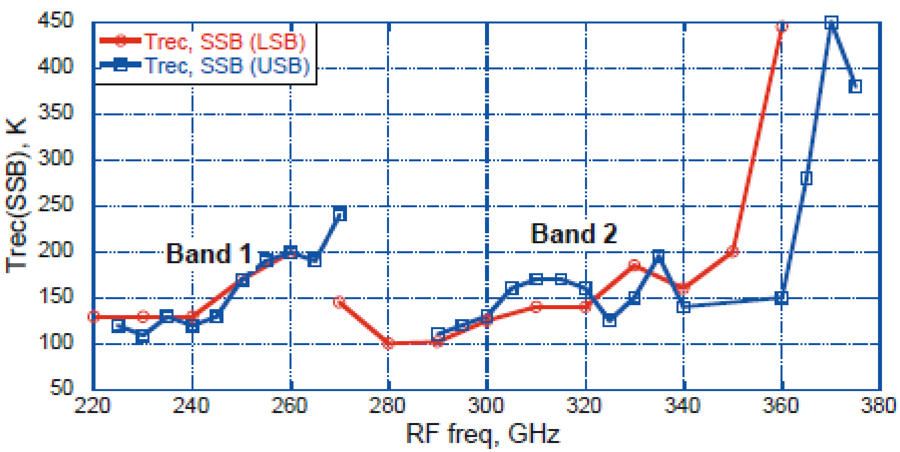
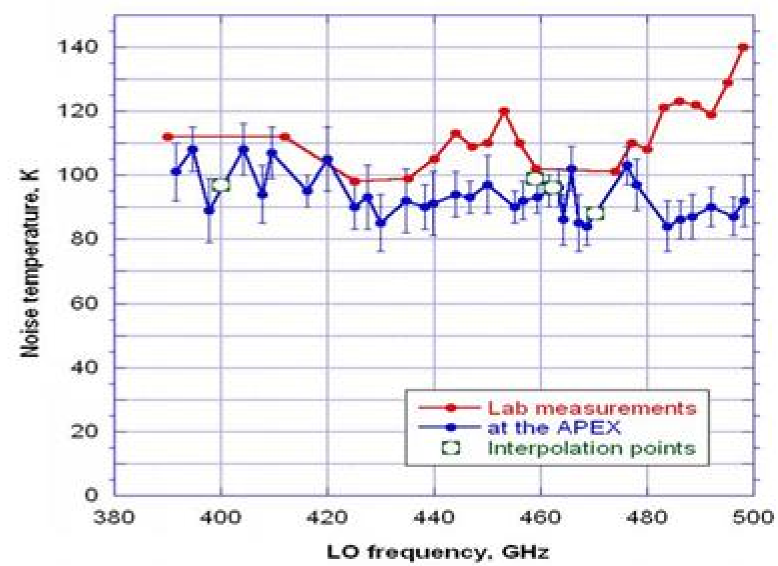


Fig. 5. Band 1, 2 SSB noise temperatures for both sidebands measured with the facility calibration unit.



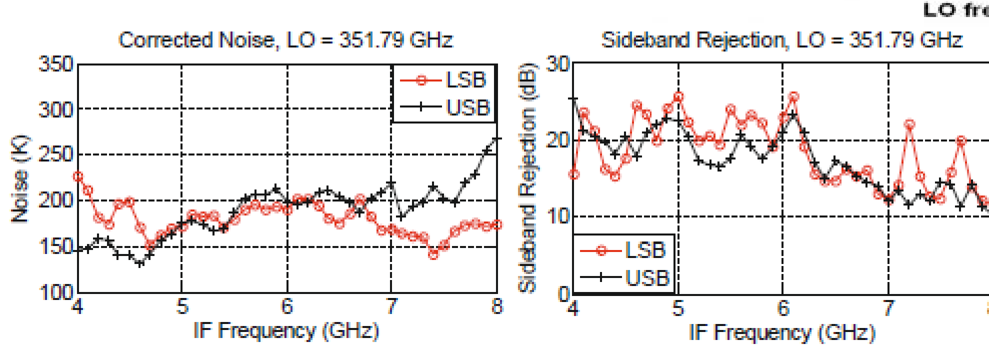


Fig. 7. Band 2 after the installation on the telescope. The SSB noise temperature for both sidebands (*left*) and the SRR (*right*).

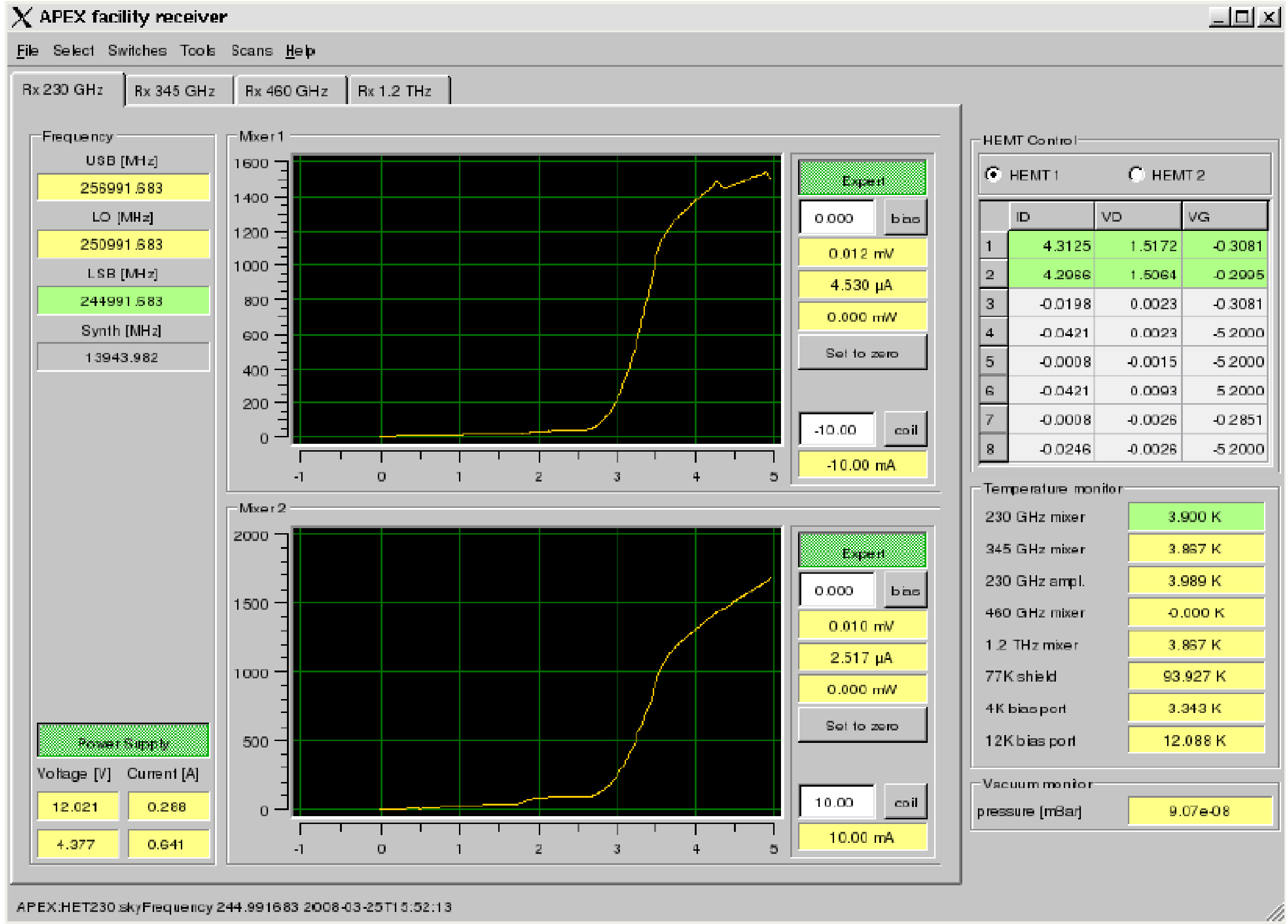


Figure 2: Pumped IV curves for APEX-1

Quick guide to tuning

The tuning GUI can be found

If the GUI is not running, open an xterm in the vnc window, cd to `facility`, and run: `./shfi`. (Check this out, could change depending the patch installed)

1. select a receiver channel under the "Select menu"
2. choose **Init band** under "Tools menu"
3. wait until relevant HEMT amplifiers are on, and defluxing (for SIS) bands has been performed.
4. wait for the IV curves to finish, and inspect them to look for flaws
5. **NOTE:** The IV curves should **not** be centered at (0,0), which we previously have been instructed. The values in the "File-> Config" menu should be calculated using a method described in "Report Re-tuning of SHeFI B2 receiver", dated 2009-09-14/2010-01-15. The procedure should be carried out during technical time once every 2 months. The values should be recorded in on SHeFIBiasOffset
6. (for SIS bands: one can perform additional defluxing (via "Tools menu") and IV scans (via "Scans menu") until mixer curves look ok.)
7. Send the frequency from the APECS system. Then once the frequency is loaded in the GUI, select sky frequency and sideband via "Tools->Set frequency".
8. choose then "Tools->Tune LO".
9. Wait until you have the message "tuning LO done!" in the bottom left corner of the GUI.

Letter to the Editor

High-resolution wide-band Fast Fourier Transform spectrometers

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ABSTRACT

We describe the performance of our latest generations of sensitive wide-band high-resolution digital Fast Fourier Transform Spectrometer (FFTS). Their design, optimized for a wide range of radio astronomical applications, is presented. Developed for operation with the GREAT far infrared heterodyne spectrometer on-board SOFIA, the eXtended bandwidth FFTS (XFFTS) offers a high instantaneous bandwidth of 2.5 GHz with 88.5 kHz spectral resolution and has been in routine operation during SOFIA's Basic Science since July 2011.
We discuss the advanced field programmable gate array (FPGA) signal processing pipeline, with an optimized multi-tap polyphase filter bank algorithm that provides a nearly loss-less time-to-frequency data conversion with significantly reduced frequency scallop and fast sidelobe fall-off. Our digital spectrometers have been proven to be extremely reliable and robust, even under the harsh environmental conditions of an airborne observatory, with Allan-variance stability times of several 1000 seconds.
An enhancement of the present 2.5 GHz XFFTS will duplicate the number of spectral channels (64*k*), offering spectroscopy with even better resolution during Cycle 1 observations.

Key words. Instrumentation: spectrographs – Techniques: spectroscopic

XFFTS

- Fast field programmable gate array (FPGA) chips
- + high sampling rates of ADCs
- → compute FFT of input signal and sum up

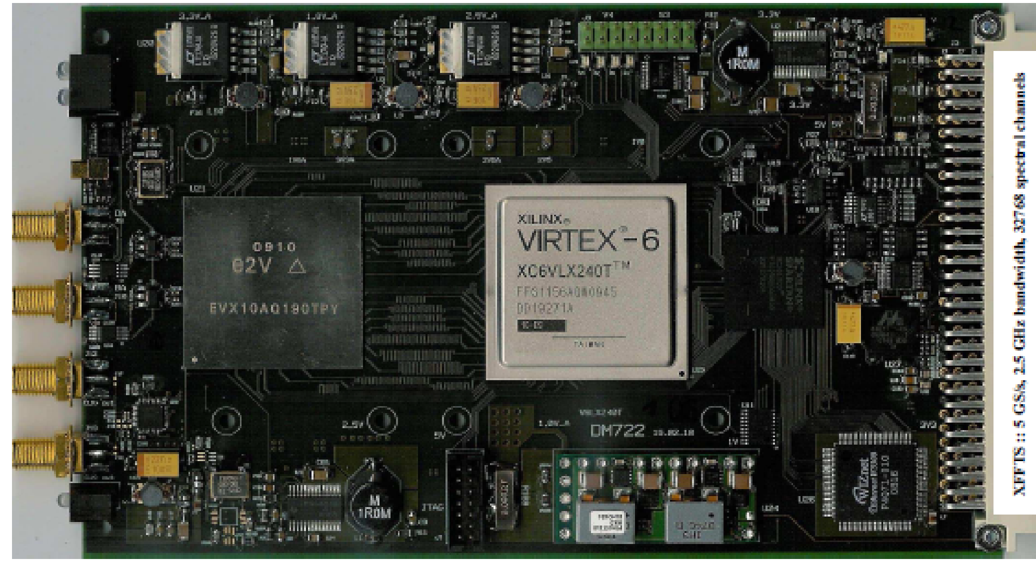

Fig. 4. XFFTS board that uses E2V's fastest 4 × 1.25 GS/s 10-bit ADC and the high-performance Xilinx Virtex-6 LX240T FPGA. By applying time interleave techniques, the four 1.25 GS/s ADCs can be combined into two 2.5 GS/s or one 5 GS/s converter. The XFFTS allows analyzing an instantaneous bandwidth of 2.5 GHz with 32*k* spectral channels. Depending on the processing set-up and the input signal level, the board consumes 20 – 25 Watt.

Fig. 5. Photograph of the 19-inch XFFTS-crate, equipped with eight XFFTS-boards (hence processing 20 GHz signal bandwidth) and one FFTS-controller unit. The modular concept allows combining multiple crates to build large FFT spectrometer arrays.

XFFTS

- 2.5 GHz
- 32768/65536 ch.
- Up to 38kHz @ 0.03km/s (360GHz) resolution
- 2 Facility XFFTS for SHFI
- 8 for FLASH+
- Large bandwidths (sets of 2 to cover 4 GHz chunks) and very stable !

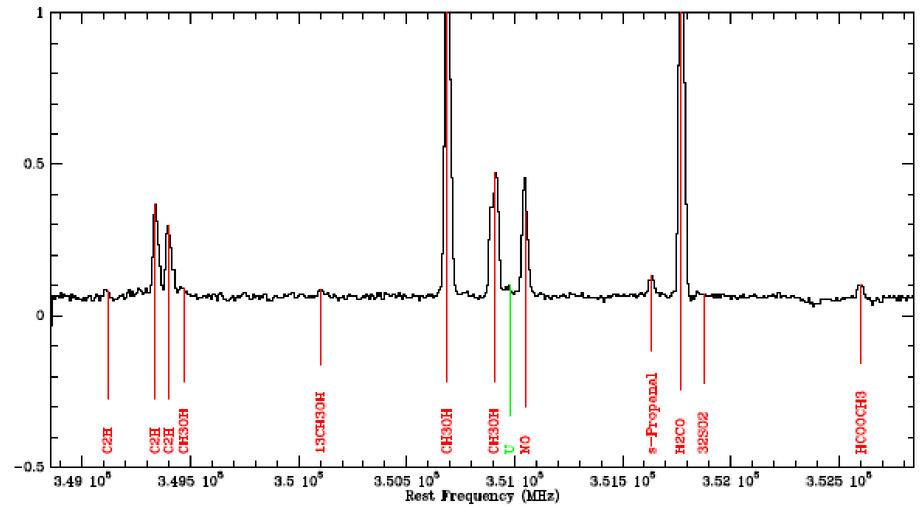

Fig. 11. Two 2.5 GHz XFFT boards combined, with 500 MHz overlap, to create a 4 GHz-wide spectrometer. The sample spectrum, part of a Galactic Center line survey (Güsten, priv comm.), shows the upper side-band of the sideband separating APEX/FLASH$^+$ receiver.

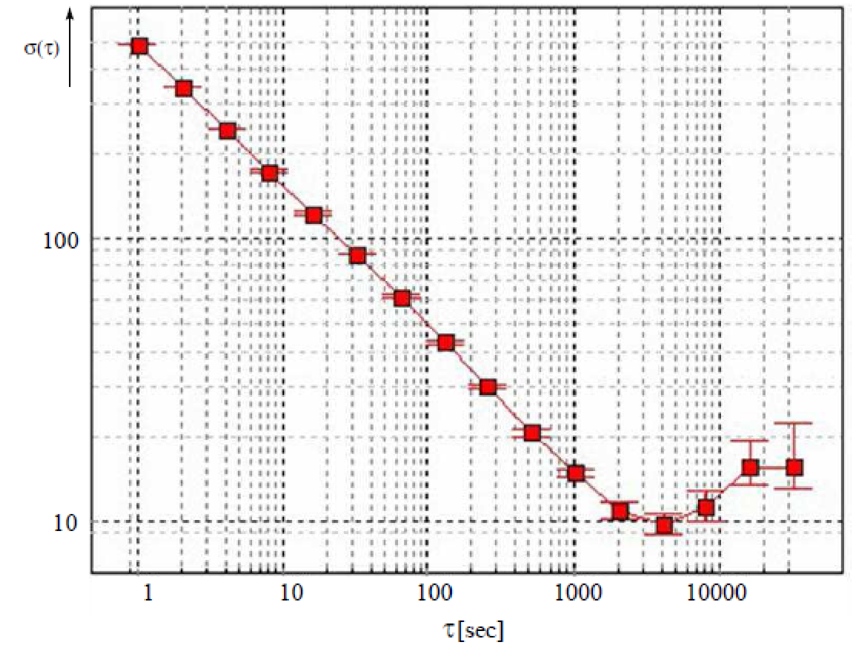

Fig. 10. Remarkable stability of the FFTS is illustrated in this Allan-variance plot. The spectrum of a laboratory noise source was integrated and processed in the AFFTS. The spectroscopic variance between two ~ 1 MHz (ENBW) wide frequency channels, separated by 800 MHz within the band, was determined to be stable on a time scale of ~ 4000 s.

AFFTS

- 28 FFTS
- Used for CHAMP+
- 1.5GHz per unit
- 8192 channels per unit