The Next Generation of Fast Fourier Transform Spectrometer

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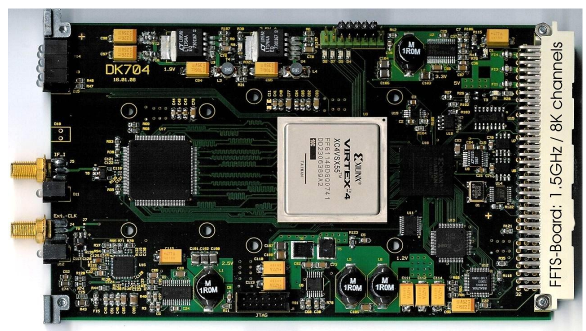
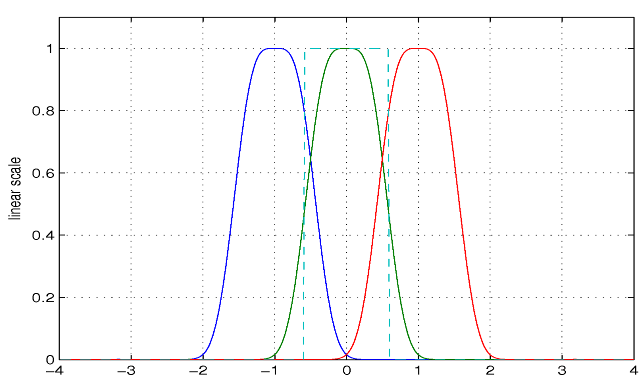
At the Max-Planck-Institut für Radioastronomie (MPIfR) we have developed our second generation of wide-band Fast Fourier Transform Spectrometer (FFTS). The new analyzer boards make use of the latest versions of GHz analog-to-digital converters and the most complex FPGAs commercially available today. These state-of-the-art chips have made possible to build digital spectrometers with coherent bandwidths of up to 1.8 GHz and up to 16384 spectral channels.

To simplify the combination of many analyzer cards into, e.g. an Array-FFTS, the novel boards include a standard 100 Mbits/s Ethernet interface. Precise time stamping of the processed spectra is realized by an on-board GPS/IRIG-B time decoder. The compact FFTS board (100 x 160 mm) operates from a single 5 Volt source and includes a programmable ADC clock synthesizer for a wide range of bandwidth setups (100 MHz - 1.8 GHz). The power dissipation per board was measured to be less than 20 Watt. The boards are available with one or two IF inputs.



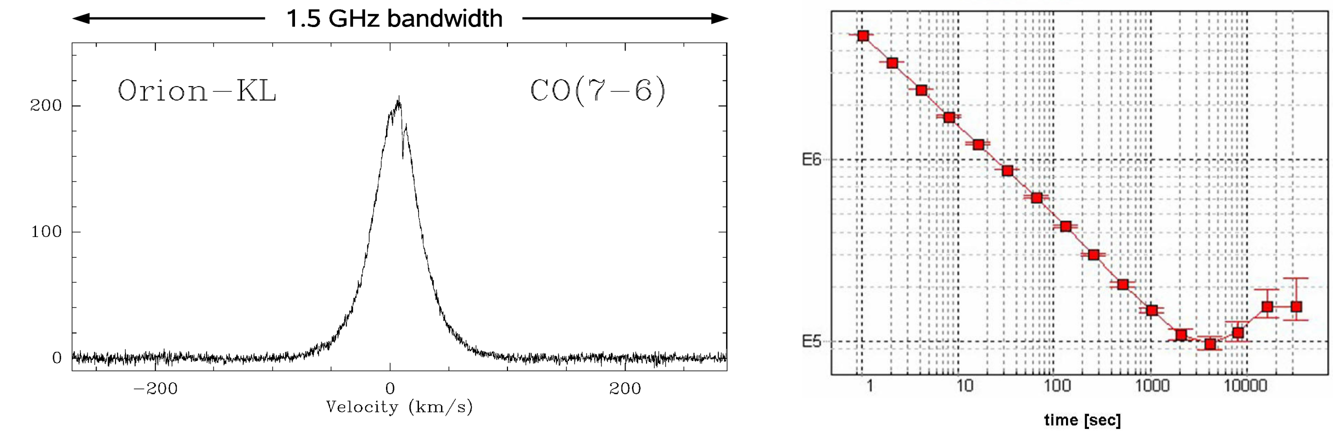
The MPIfR wide-band Array-FFTS equipped with 8 FFTS boards. A single FFTS board provides 1.5 GHz monolithic bandwidth with 8192 spectral channels. The frequency resolution (equivalent noise bandwidth) in this configuration is 212 kHz.



Frequency response of the optimized FFT signal processing pipeline. The dashed lines illustrates the equivalent noise bandwidth (ENBW) for the corresponding spectral bin.

Unlike the conventional windowed-FFT processing, a more efficient polyphase pre-processing algorithm has been developed with significantly reduced frequency scallop loss, less noise bandwidth expansion, and faster sidelobe fall-off.

The superior performance, high sensitivity and reliability of the FFTS has now been demonstrated at many telescopes world-wide, including APEX (Chile), CSO (Hawaii), 30-m IRAM (Spain) and the 100-m Effelsberg observatory (Germany).



First light spectrum of the new MPIfR 1.5 GHz wideband FFT spectrometer towards the hot core Orion-KL. The high-excitation CO(7-6) transition at 806 GHz was observed with the central pixel of the CHAMP+ array at APEX (24. Oct 2008). To the right, an Allan-Variance-Plot illustrates the superior stability of this FFTS. Data from a 1 GHz noise source were processed in 1 MHz bins. The spectroscopic variance between two 1 MHz broad channels, separated by 600 MHz within the band, was determined to be stable on a timescale of ~4000 s.

Today, implemented FFTS board / FPGA configurations are

1 x 1.5 GHz bandwidth, 1 x 8192 spectral channels, ENBW: 212 kHz
1 x 500 MHz bandwidth, 1 x 16384 spectral channels, ENBW: 35 kHz
2 x 500 MHz bandwidth, 2 x 8192 spectral channels, ENBW: 71 kHz (in lab test)

Note, that the bandwidth can be changed by software.

Advantages of the new MPIfR-FFTS

We summarize the striking advantages of this new generation of compact FFT spectrometers:

- FFTS provide high coherent bandwidth (1.5 GHz demonstrated in field tests, 1.8 GHz achieved in lab tests) with many thousand frequency channels, thus offering wide-band observations with high spectral resolution without additional IF processing.
- They provide very high stability by exclusive digital signal processing. Allan stability times of ~4000 seconds have been demonstrated routinely.
- Field-operations of our FFTS over the last 3 years has proven to be very reliable, with calibration- and aging-free digital processing boards, which are swiftly re-configurable by Ethernet for special observation modes.
- Low space and power requirements – thus safe to use at high altitude (e.g. APEX at 5100-m) as well as on spacecrafts and satellites.
- Production cost are low compared to traditional spectrometers through the use of only commercial components.

Contact

For further information about our FFT spectrometers, future developments and applications, please contact Dr. Bernd Klein (bklein@mpifr-bonn.mpg.de) at the Max-Planck-Institut für Radioastronomie in Bonn, Germany.

2008-04-18 Bernd Klein