Evaluation of new high-performance spectrometer and spacecraft tracking software

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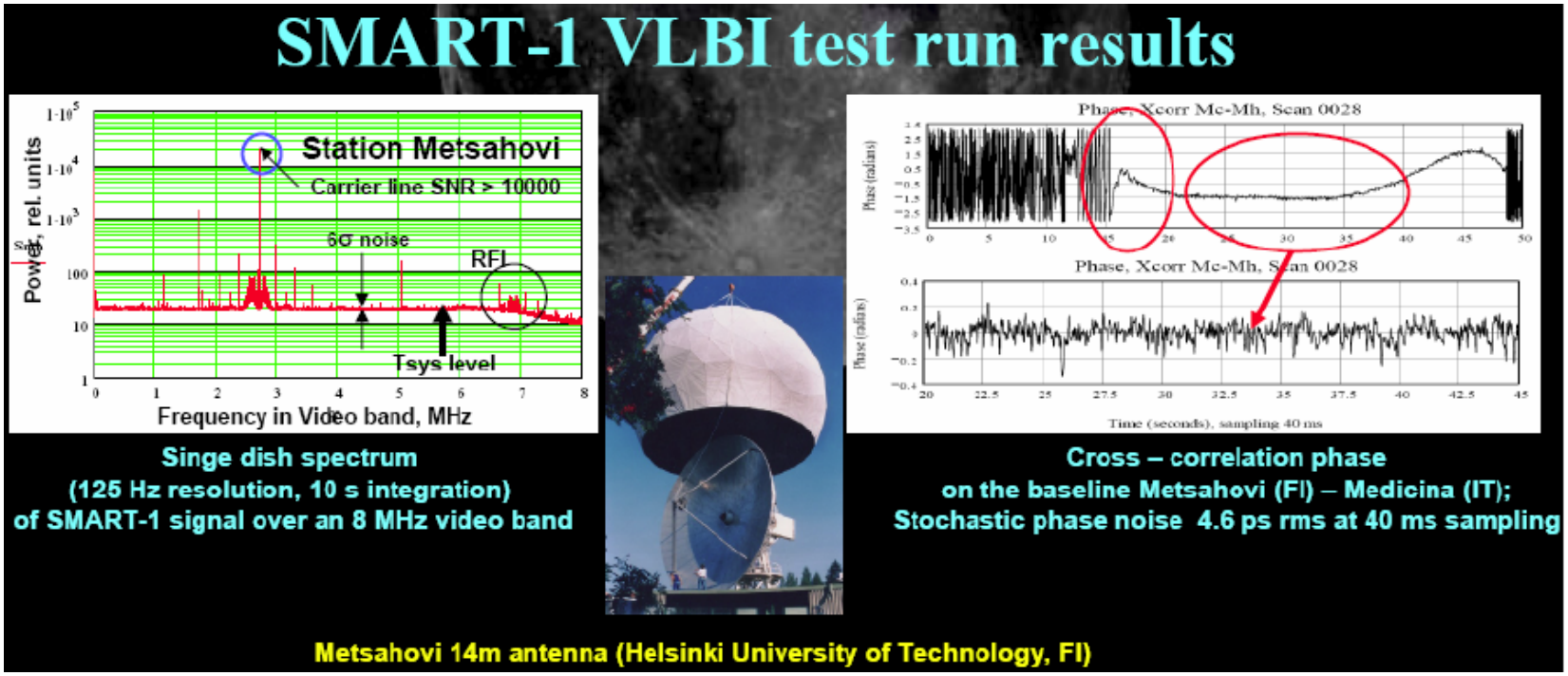
Reasoning

- New instr. hardware achieve better spec purity, sensitivity…
  => always finding new applications, improved methods



- Previous S/C tracking projects VEGA (Venus), Huygens (Saturn/Titan), ESA SMART-1 (Moon), VEX, MEX, …
- JIVE, Mh developed new evaluation set of software tools

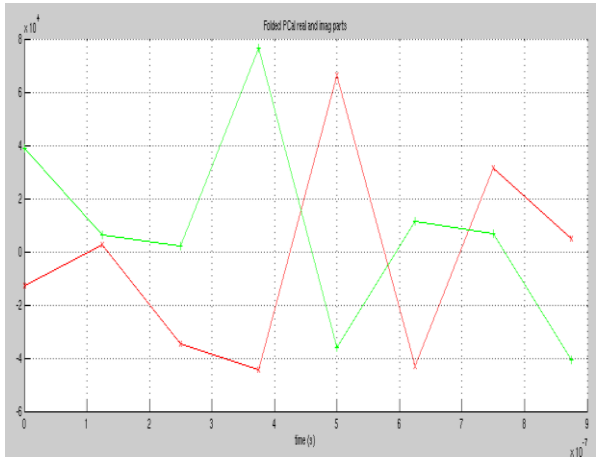
Software tools

A set of programs and scripts for astronomical and space science applications

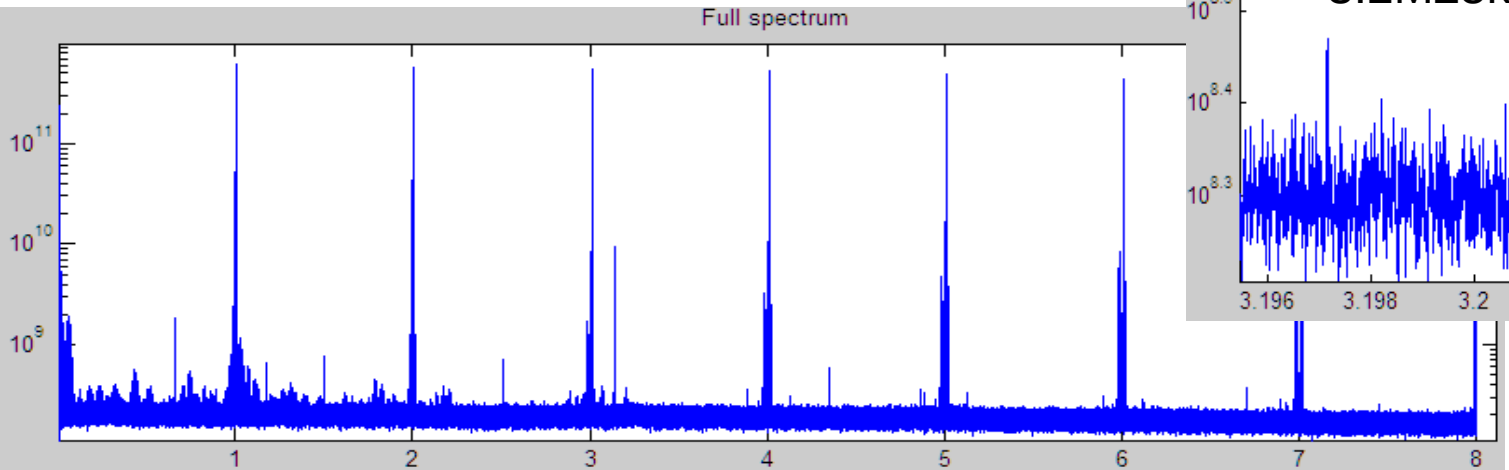
1. SWSpectrometer
   - a (yet another) new inexpensive, effective multi-functional spectrum software for e.g. single-dish classic spectroscopy
   - fast vectorized processing on Intel and PS3/Cell
   - emphasis on spectrum accuracy, arbitrary integration times
2. SCTracker
   - high performance pre-processing for single and multi-dish probe and S/C tracking experiments, using the phase referencing method
3. Tracker post-processing tools:
   - improved JIVE toolset for S/C tracking with e.g. sctracker output data
   - together with sctracker got 100-fold speed improvement of the method

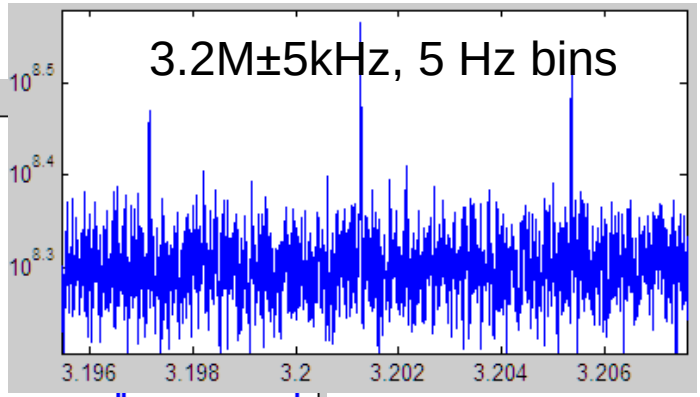
SWSpectrometer

- New fast 'classic' spectrometer
  - windowed overlap add, float/double
  - auto- and cross-correlation, ~16Ms/s/core
  - phase cal extraction: very fast multi-tone method a la Sergei, code reusable
  - evaluated against maser, MEX/VEX S/C
  - the most accurate sw spectrometer to date?



- Can run by schedule to detect e.g. S/C carrier semi-realtime
- Nice tool to check station signals generally, or really use as an accurate integrating spectrometer





SCTracker

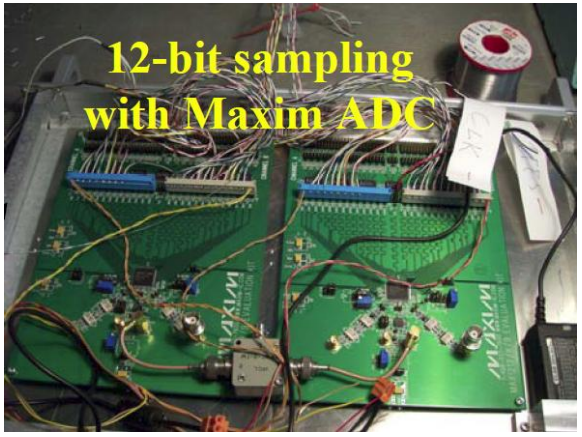
- Idea was to exercise things, evaluate if EVN stations, the method and software could be used for tracking S/C, debris, planet orbiter or faint balloon and so on
- Assess performance of inexpensive software and data acquisition for S/C tracking purposes?
- Evaluate systems that could be deployed at stations interested in such space science VLBI and balloon and other missions under ESA Cosmic Vision

- All that using some DAQ hardware, new software, trial JIVE analysis tools

Data acquisition for the SWS/SCT

Standard observation schedule, FS antenna control

RF/IF front-ends, VLBA DAR, …



2-bit. PC-EVN VSIB

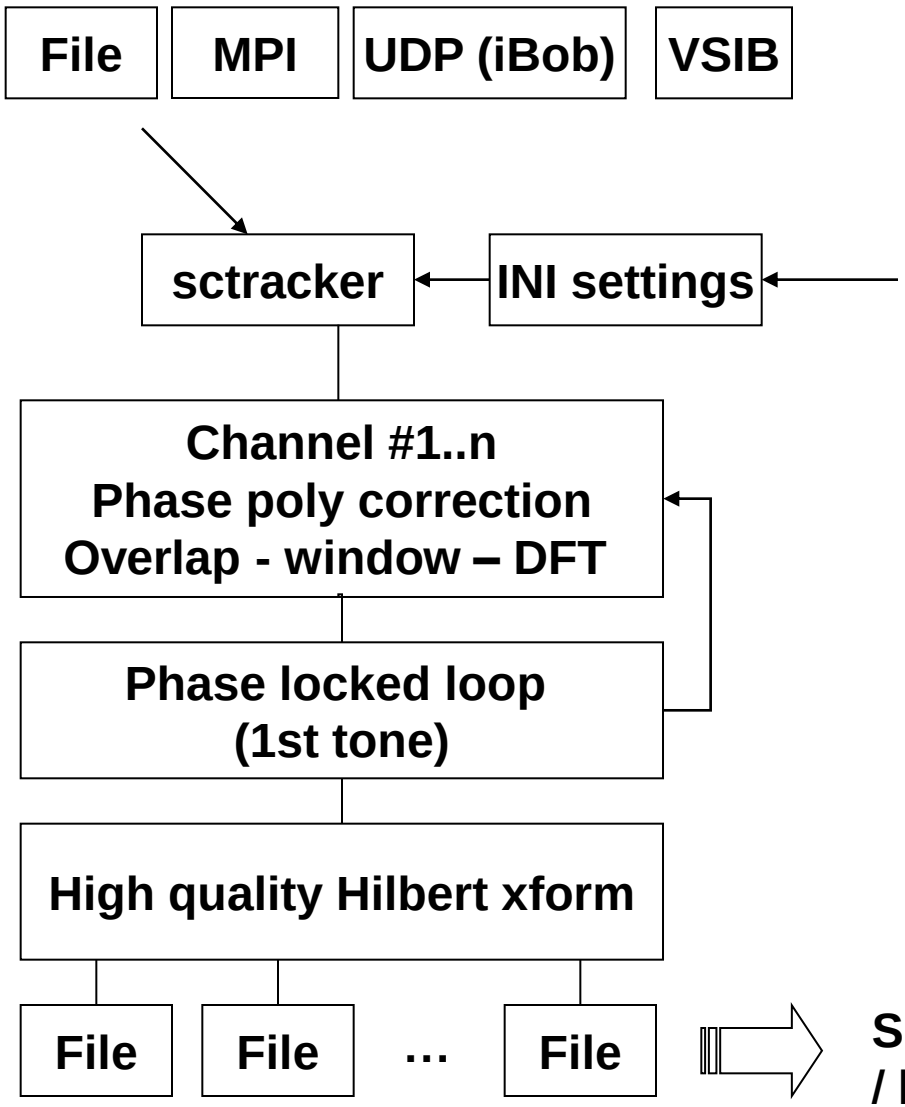
2-bit. Mark5A/B

UDP/IP or VSI capture
Store data as files

Batch-runnable spectrometer, S/C carrier + lock software on Intel or PS3

Post-processing of spectra and extracted S/C tones, ff correlation

SCTracker




```
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BandwidthHz = 8000000
SecondsToSkip = 0

PhasePolySign = -1
PhasePolyOrder = 5
PhasePolyCpmFile = Cpp.scan01.rad.txt
PhasePolyCoeffType = SampleBased

FFTpoints = 320000 # 320k points
FFTIntegrationTimeSec = 20.0 # 20s
FFToverlapFactor = 2 # 50% overlap
WindowType = Cosine
FilterBandwidthHz = 2000 # 2kHz
ToneOffsetsFile = FOffsets.txt
NumCores = 4
...
```

A priori phase polynomial

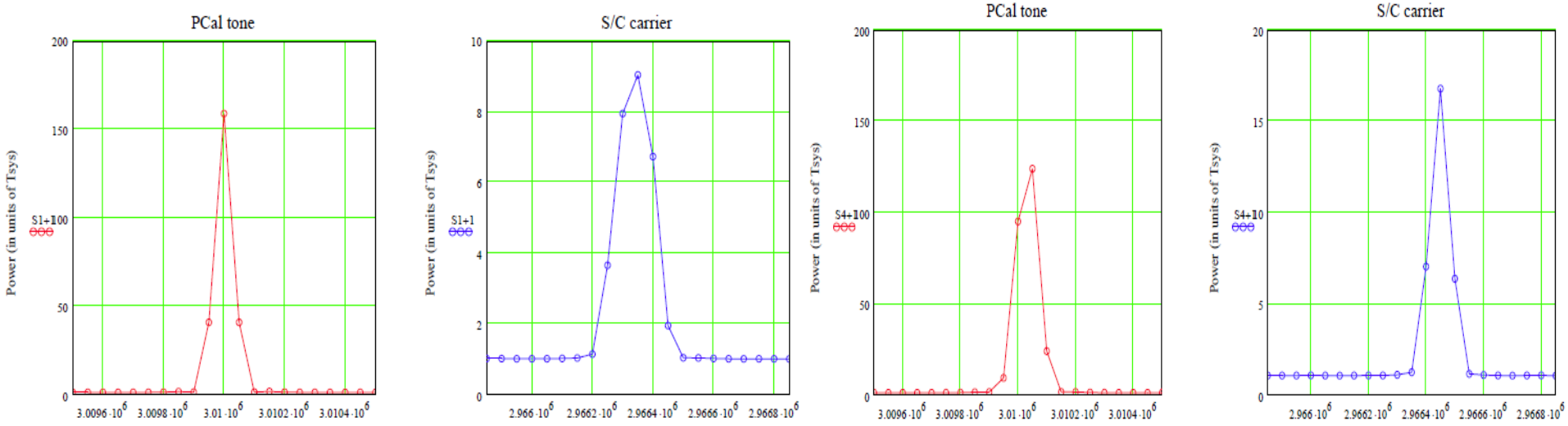
List of tones

Slower post-processing with Matlab / MathCAD / … for final phase

Polynomial phase correction

- All computation has to be 64-bit / double precision
- Fast SIMD-vectorized poly correction, only about 15% slowdown when going from 3rd to 16th order correction
- Coefficients are from PLL or manual fit into spectrum series

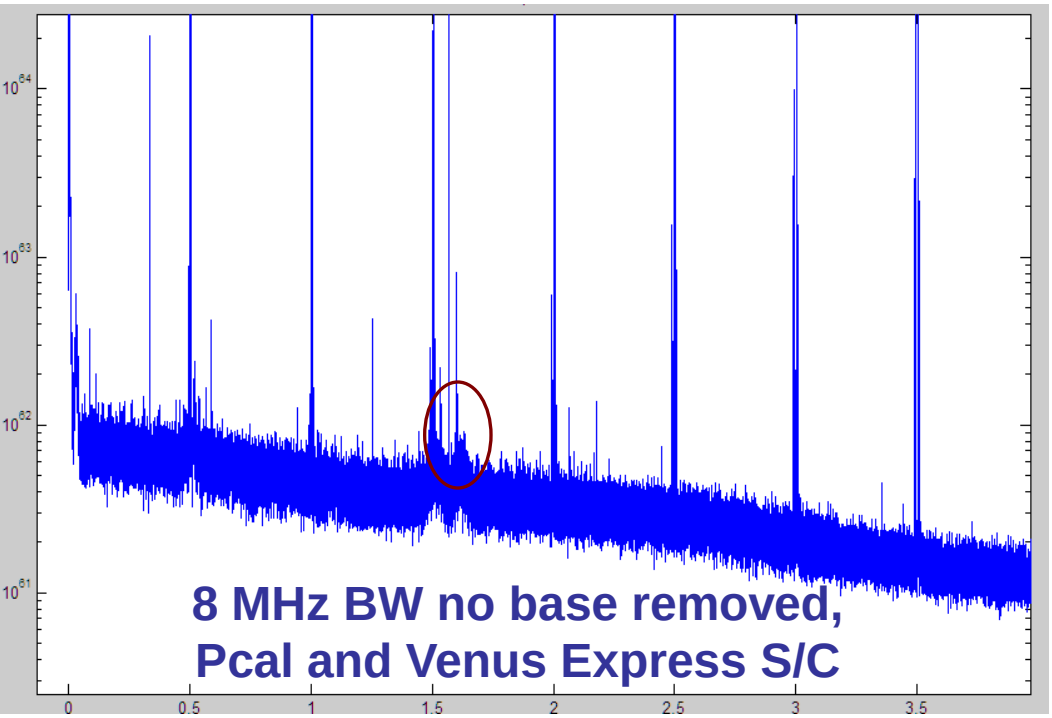
Venus Express 10 minute integrated 320k-point spectrum
PCal and S/C carrier

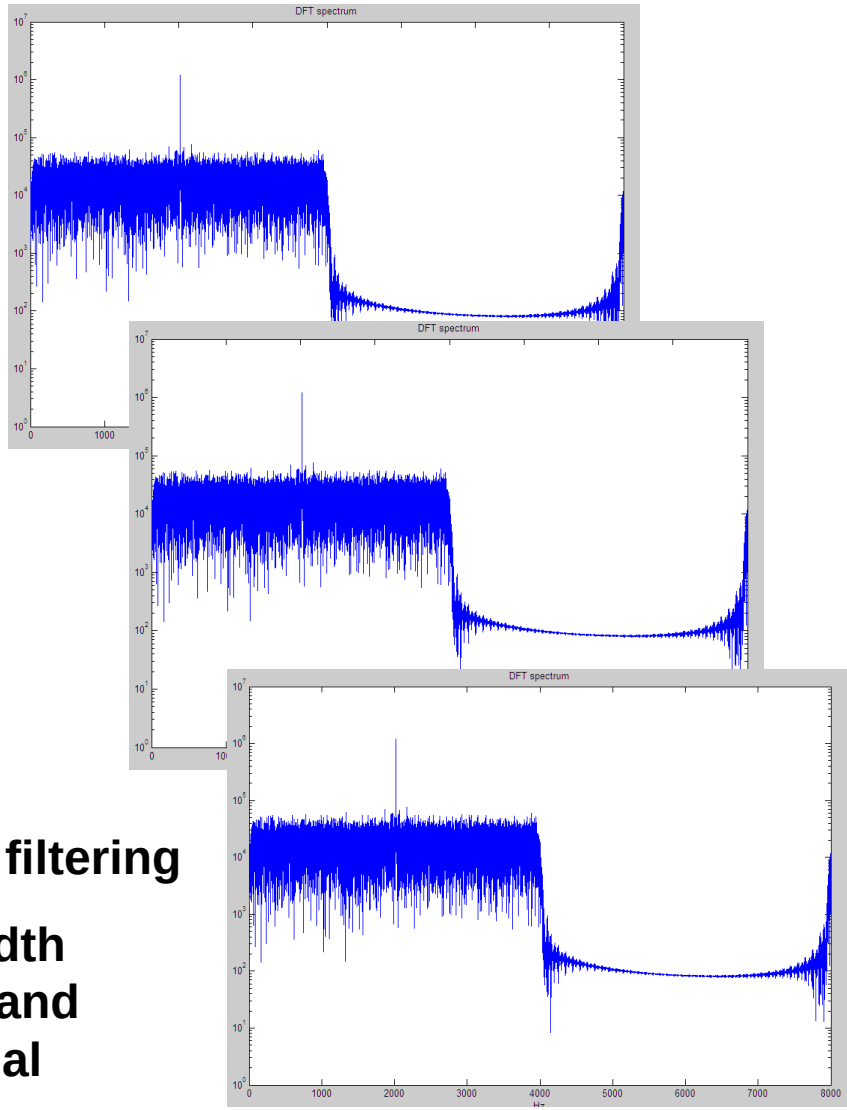


Uncorrected spectrum
Left: PCal, Right: S/C

Simple 3rd order correction stopping S/C motion, ~single bin component

Hilbert transform outputs



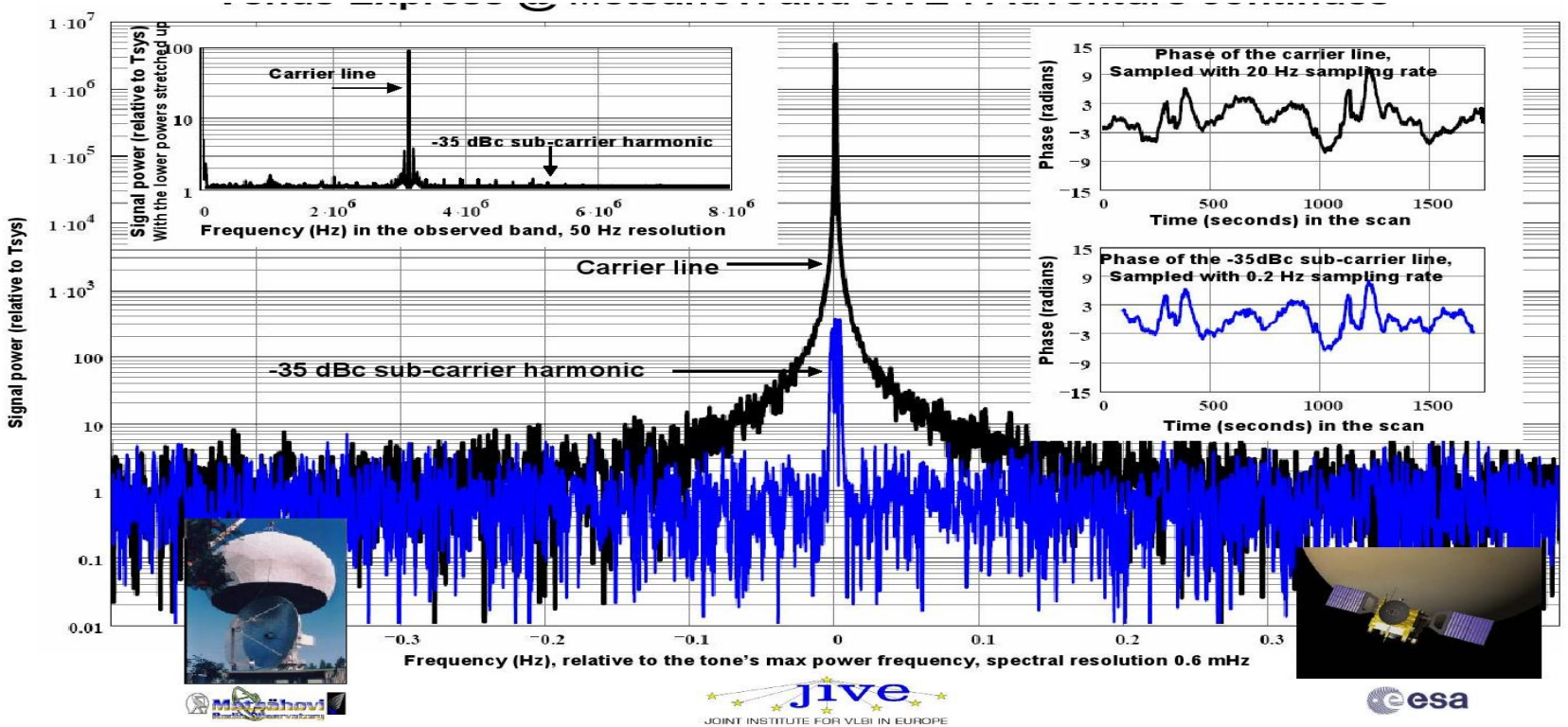


- **SCTracker does the fast pre-processing: S/C carrier track, first phase-stop, 40-80 dB filtering**
- **Next, precision stopped filtered low-bandwidth signals are input into JIVE post-processing and analysis for several further steps and residual phase correction => sub-milliherz, high-DR**

Extracted tones 4kHz BW Real-valued signals

Post-processing

- By Sergei P. et al, JIVE, for high accuracy analysis
- Uses further filtering and the various phase models as input to get the residual phase
- Consists of a set of MathCAD & co scripts and tools



Summary

- Free software tool for high-resolution spectroscopy, configure as you like
- SCTracker to speed up phase-referenced S/C tracking, evaluated with VEX observations
- JIVE software tools for involved post-processing

  => Deployable HW + SW S/C package for stations

- Next, did not try VLBI – yet
  - Medicina-Mh Ulysses observation w/ iBob 27-28.11.
  - Space Debris tracking with Medicina?
- Next 2, correlation for far field phase delay model