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### **Hard- and software tools for the education of Geodetic VLBI**

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## SALSA

The Onsala Space Observatory hosts two 2.3 m radio telescopes called SALSA ("Such a lovely small antenna") which are utilized to bring front-line interactive astronomy to the classroom. Until now SALSA has been used for astronomical educational purposes solely, in particular demonstrating the concept of single dish measurements.



Fig. 1: Webcam image of the two SALSA antennas at the Onsala Space Observatory, taken at Feb. 22, 2016 11:00 UT (<http://vale.oso.chalmers.se/salsa/webcam>)

## Turning SALSA in an interferometer

In order to combine both SALSA antennas to a local interferometer an off-the-shelf USRP E310 stand-alone software defined radio is utilized.



Fig. 2: Photo of the USRP E310 together with a pen for better illustration of the dimensions of the device.

This small device has two independent RF front ends with flexible mixed-signal baseband sections and integrated frequency synthesizers. Overall RF frequencies between 70 MHz and 6 GHz can be translated to complex baseband and sampled with up to 56 MHz of instantaneous bandwidth. Thus, the interferometer can be realized as depicted in Figure 3.



Fig. 3: Signal chain of the SALSA interferometer.

## First light

First light was obtained on Feb. 10, 2016 14:01 by observing the Sun at 1410 MHz with 1 Msps/channel. A simple Octave based correlator has been written and fringes were obtained for a 20 ms scan (cf. Figure 4).

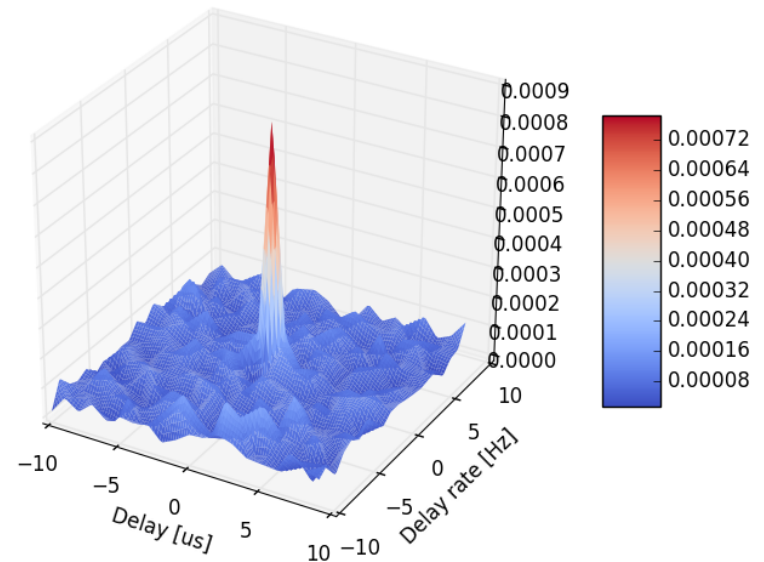


Fig. 4: Delay resolution function of a 20 ms scan of the Sun at 1410 Mhz.

## Post-processing

A 300 s scan of the Sun has been post-processed and phases, delays and amplitudes were successfully obtained every second (cf. Figure 5).

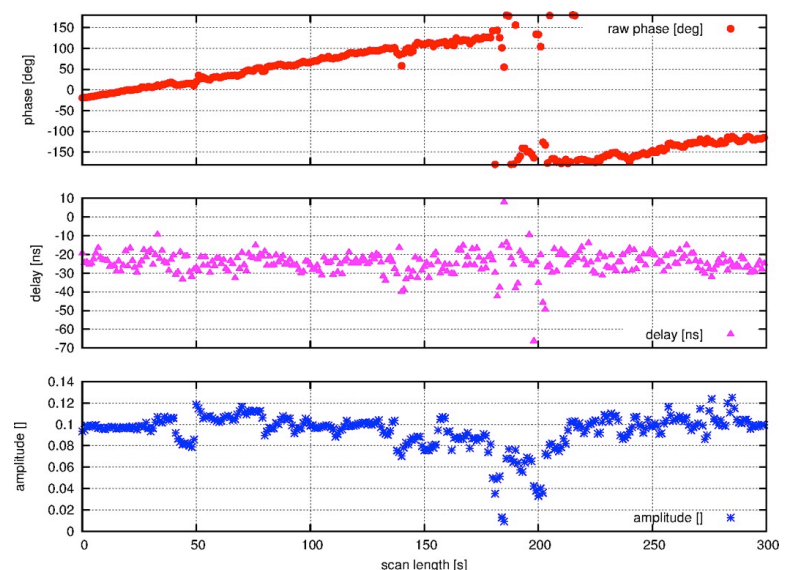


Fig. 5: Phases (upper plot), delays (middle plot) and amplitudes (lower plot) as obtained from a scan of the Sun on Feb. 10, 2016 14:03 UT.

## Next steps

Next steps include:

- Usage of a satellite tracking module in the SALSA control system
- Increase of sampling bandwidth and number of channels
- Real-time correlation and fringe detection
- Development of a post-processing chain in Octave
- Output to standard geodetic observation formats (VGOSDB, NGS)
- Geodetic analysis with c5++
- Feasibility study to carry out FFTs and/or correlation on the FPGA by means of RF Network on Chip (RFNoC)