A LOW-COST GNSS-R SYSTEM BASED ON SOFTWARE-DEFINED-RADIO

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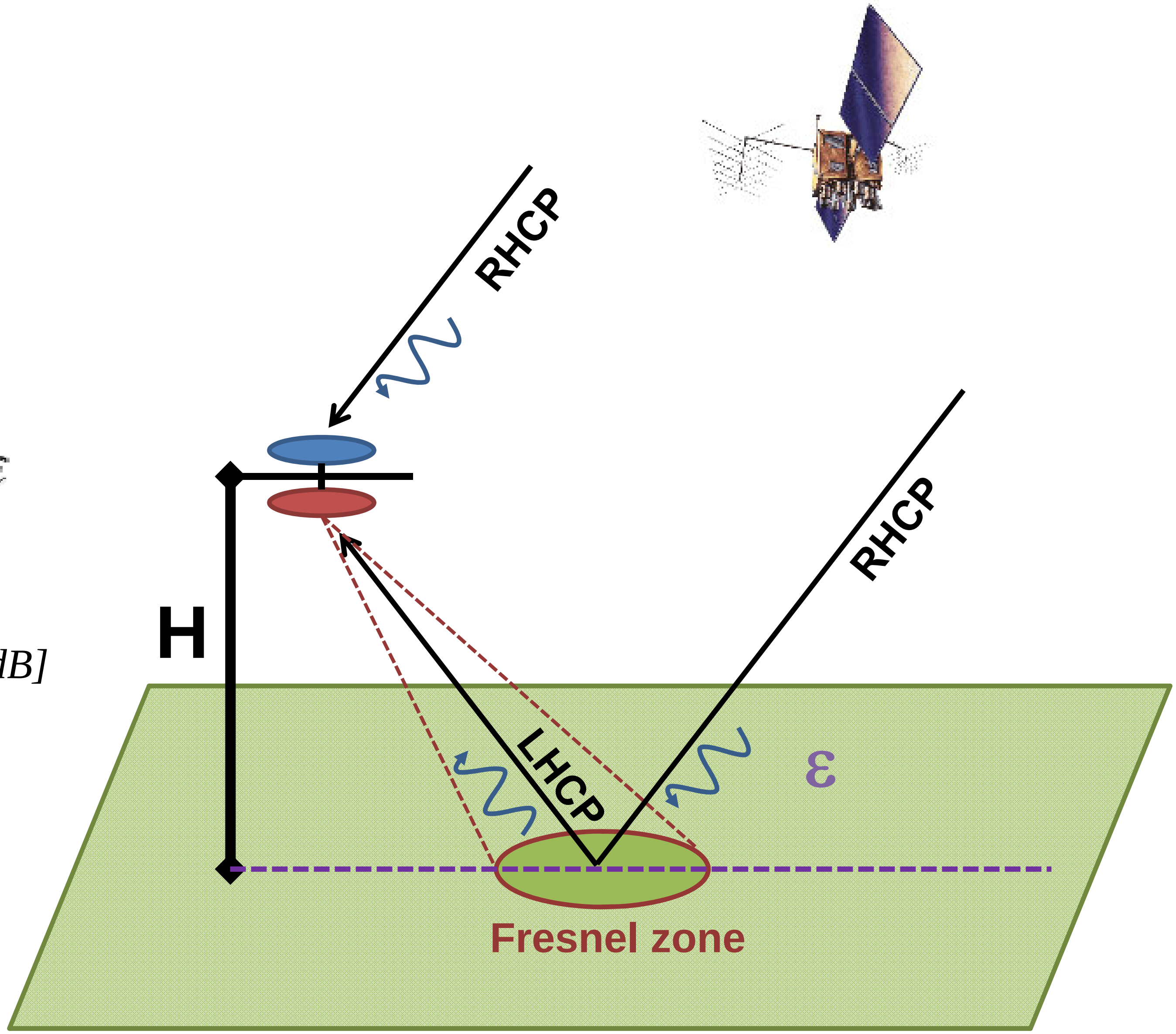
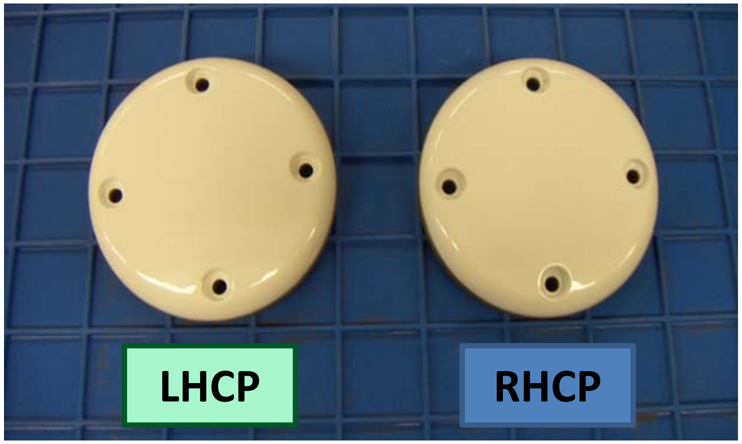
GNSS Reflectometry (GNSS-R)

$$\Delta\tau = \frac{2H}{c}\sin\varepsilon$$

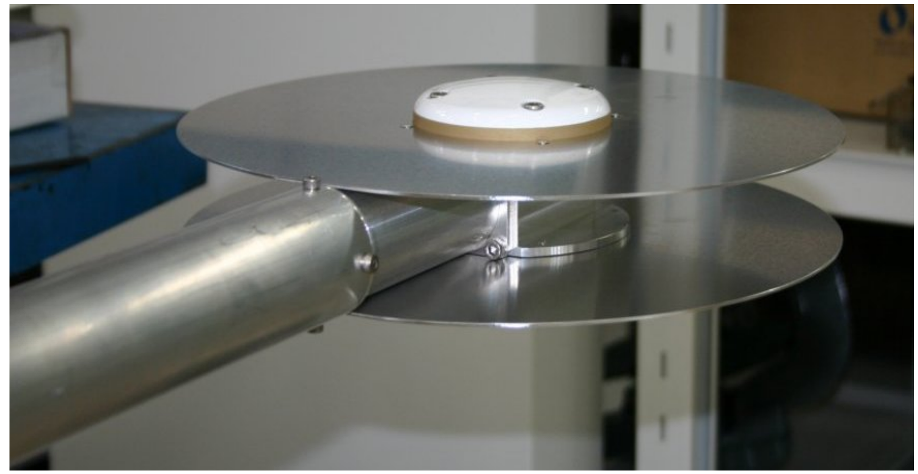
Att = RCHP–LHCP [dB]



Antenna (off-the-shelf components)



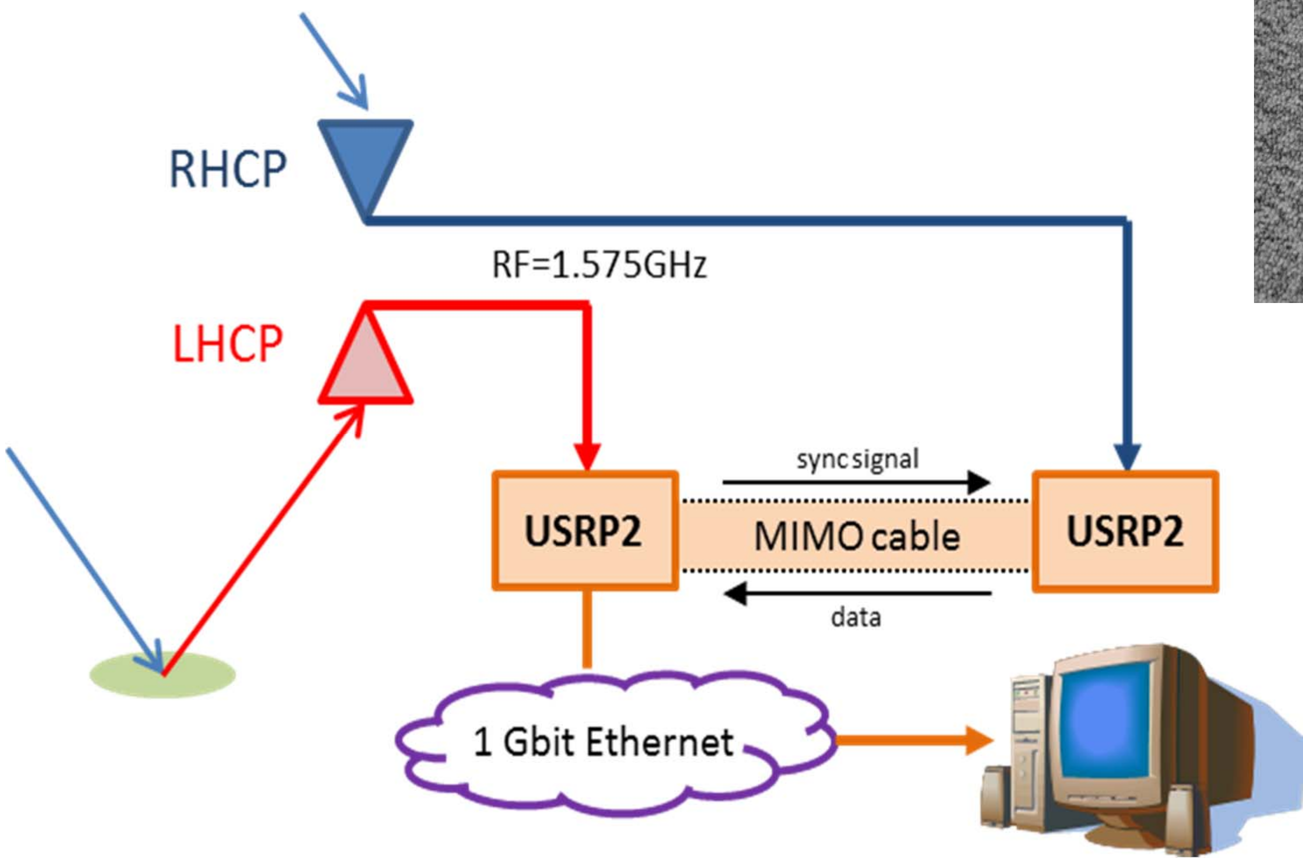
L1 antennas, 3.5’’ diameter



Deployment


NICT HQ / Tokyo
画像取得日: 2006 年 12 月 1 日
35° 42'28.49" N 139° 29'20.44"
PL－1
PL－2
4,000

Data flow



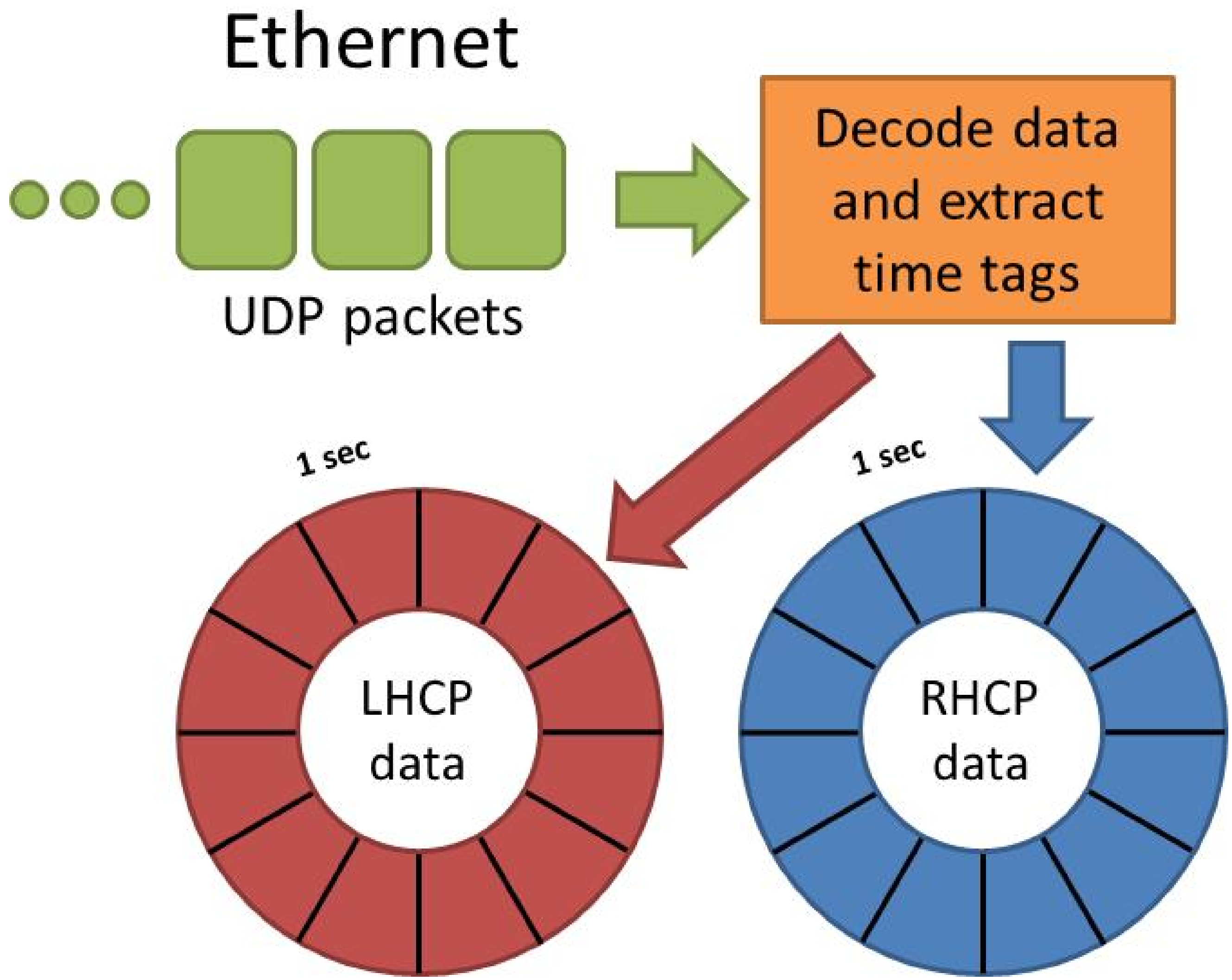
USRP2

2 GPUs (GTX580)

Software receiver

- Three modules
  ① Sampler: gets RHCP and LHCP data (6.25 Msps, complex I/Q) and puts data into circular buffer
  ② GNSS receiver: tracks all visible PRNs and computes LO offset of sampler
  ③ GNSS-R module: computes delay-doppler-maps (DDM) and writes them to binary files
- Module ② and ③ run on the GPU and thus don't conflict with the real-time data streaming of module ①.

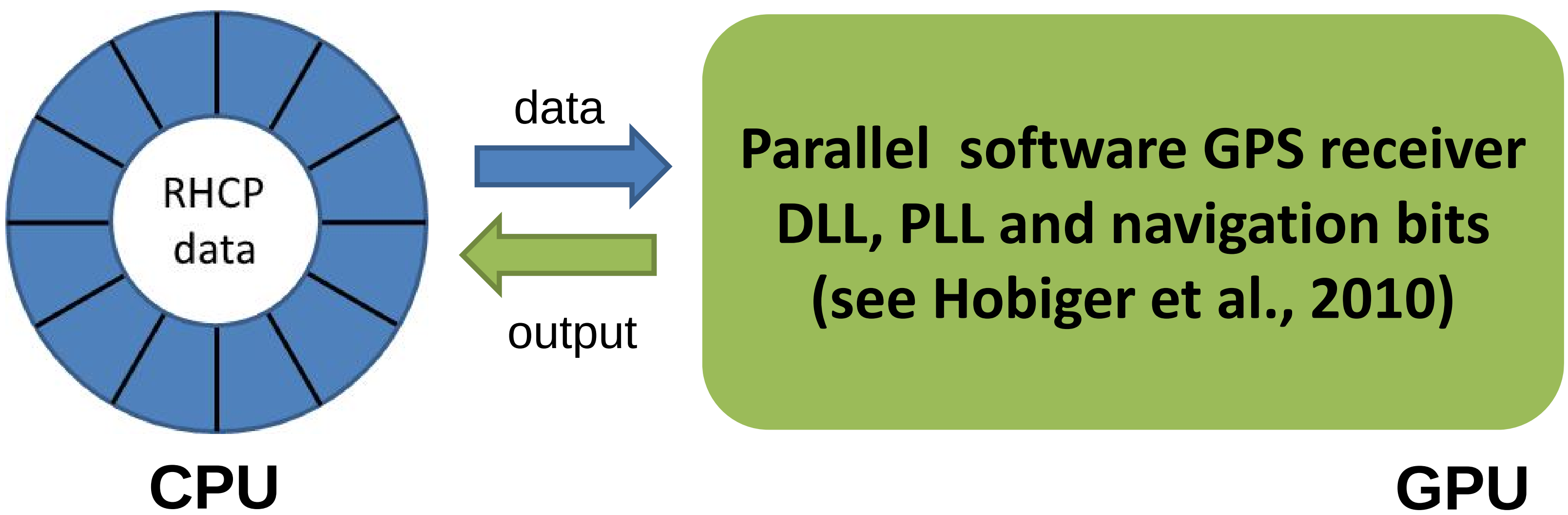
① Sampler module



②URSP local offset determination

- Clocks of the two USRPs are synchronized via MIMO cable
- BUT: internal clock of USRP (master) is free-running (only TCXO)
- Leads to unknown, quite large and varying LO offset $\rightarrow$ needs to be monitored before data can be processed
- Additionally, navigation message modulated on GPS carrier leads to ±180 degree phase jumps if the bit status changes$\rightarrow$ detection of navigation message bits necessary

②URSP local offset determination(ctd.)



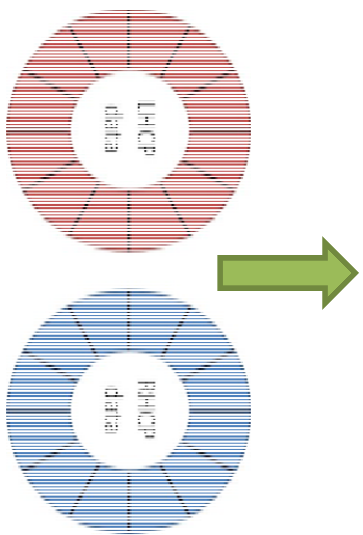
Measured Doppler shift

Computed Doppler shift

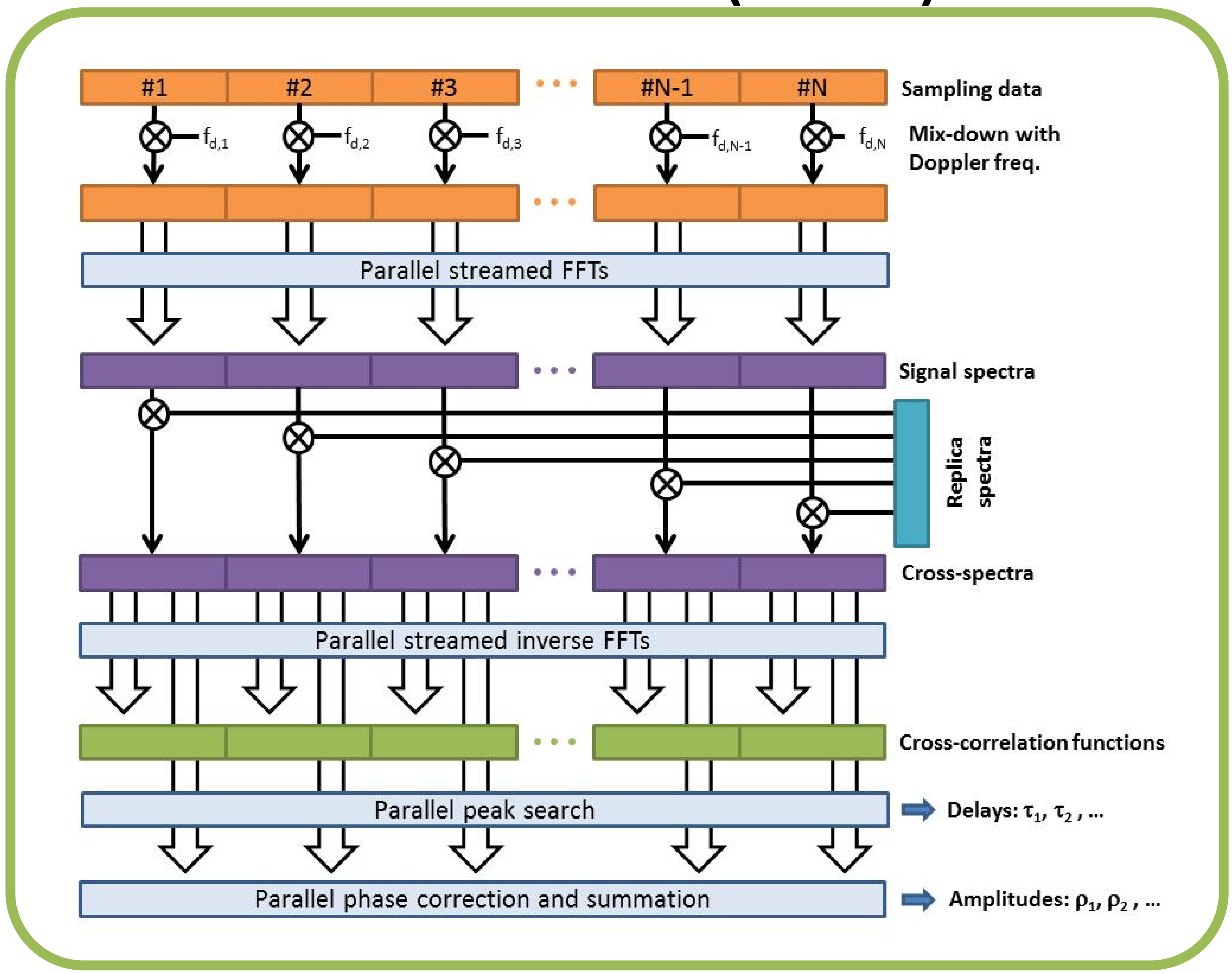
$$f_{LO} = \frac{\sum A_i (f_{d,i} - f^t_{d,i})}{\sum A_i}$$

Signal amplitude

③GNSS-R module (core)

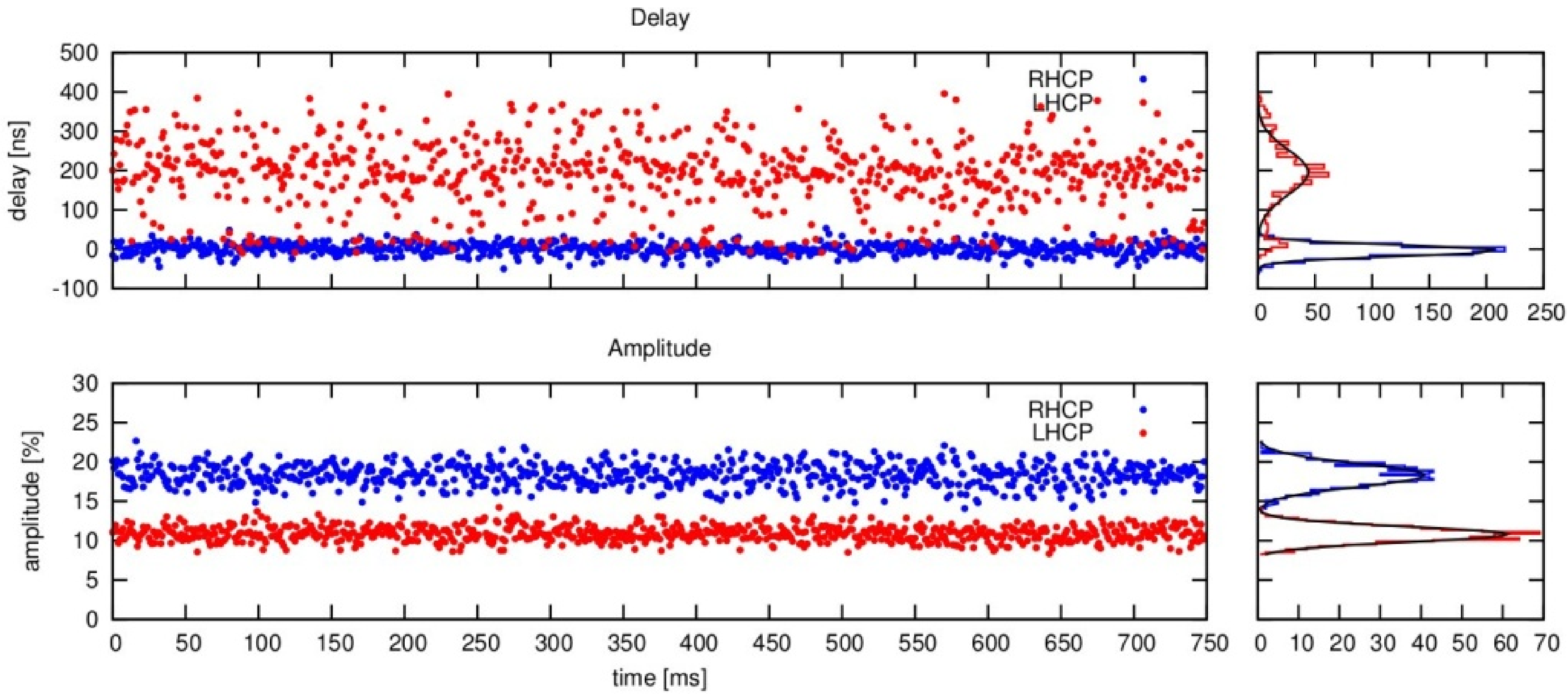


CPU



GPU

Sample output



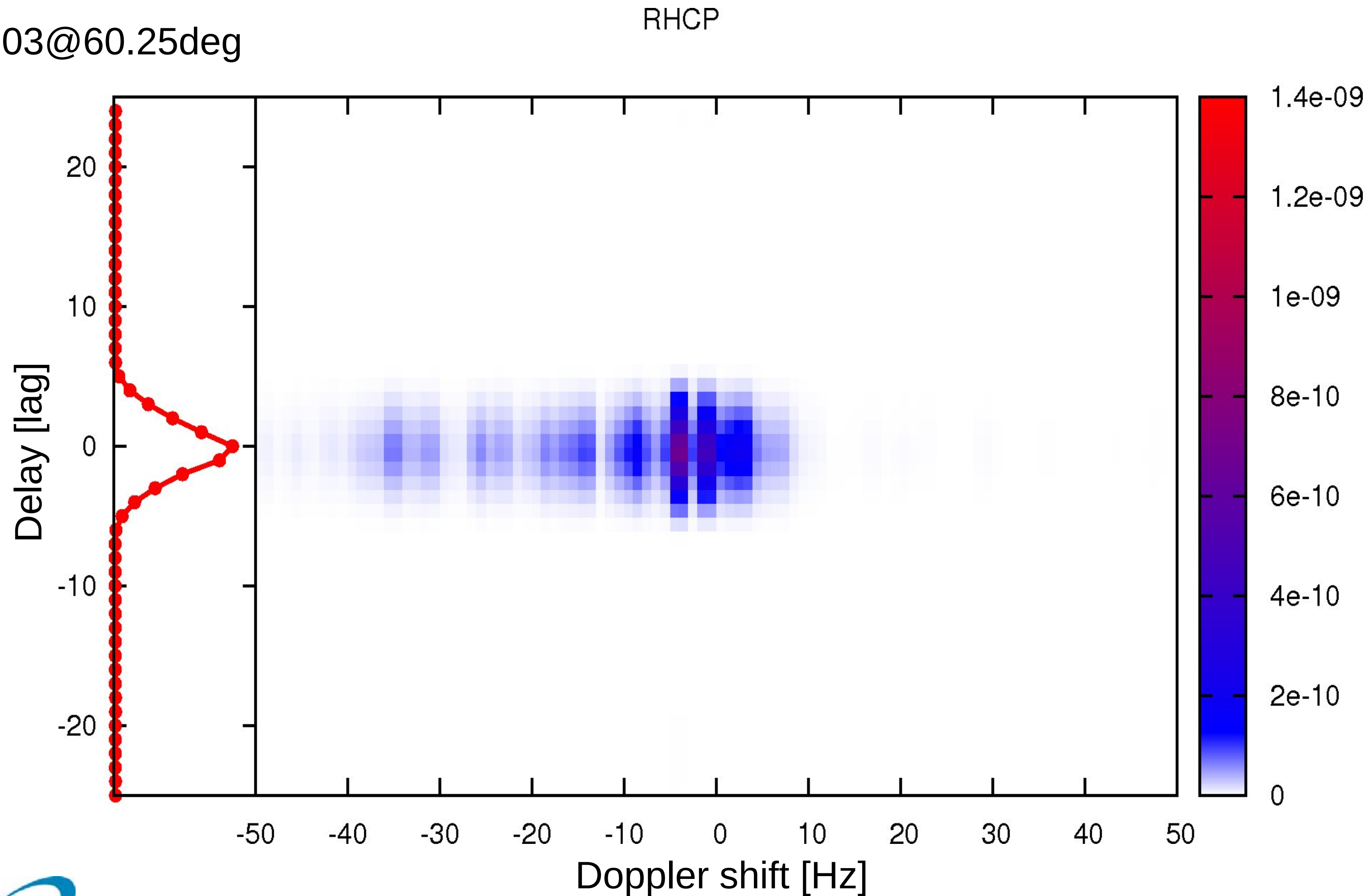
Sep. 12th, 2011 13:30:38 UTC, GPS PRN 02

Generation of Delay-Doppler maps

- Coherent integration over several milliseconds allows to derive delay and Doppler information (so called Delay-Doppler map (DDM))
- DDMs can be used to deduce geophysical parameters (e.g. sea surface roughness, winds, etc.) by comparison with theoretical models

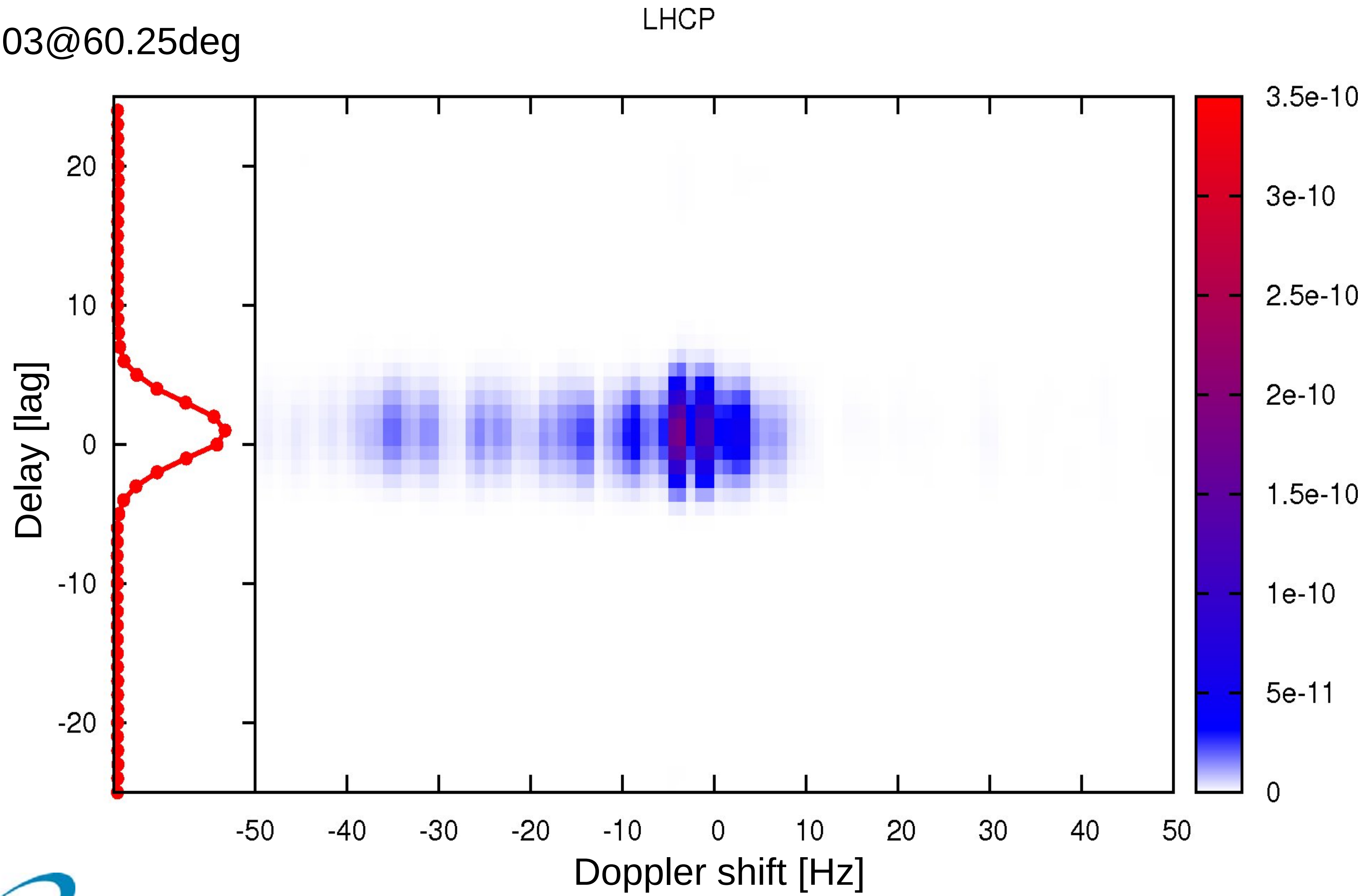
Delay-Doppler map results (RHCP, 2.048 sec coh. int.)

PRN03@60.25deg



Delay-Doppler map results (LHCP, 2.048 sec coh. int.)

PRN03@60.25deg



Long-term experiment (38 d) from Aug. 17, 2011

All visible GPS satellites in RHCP and LHCP above 45 degrees elevation were tracked

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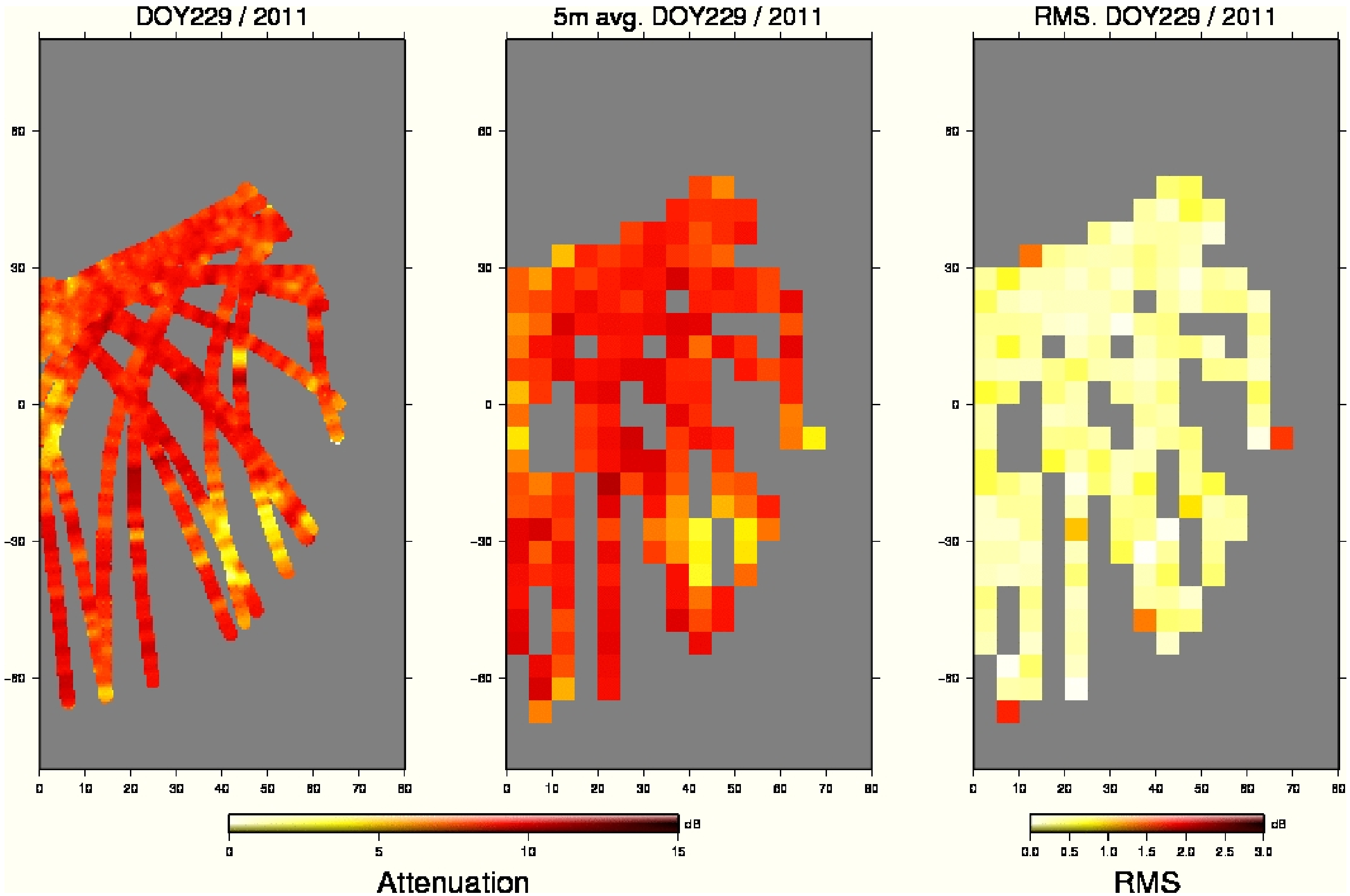
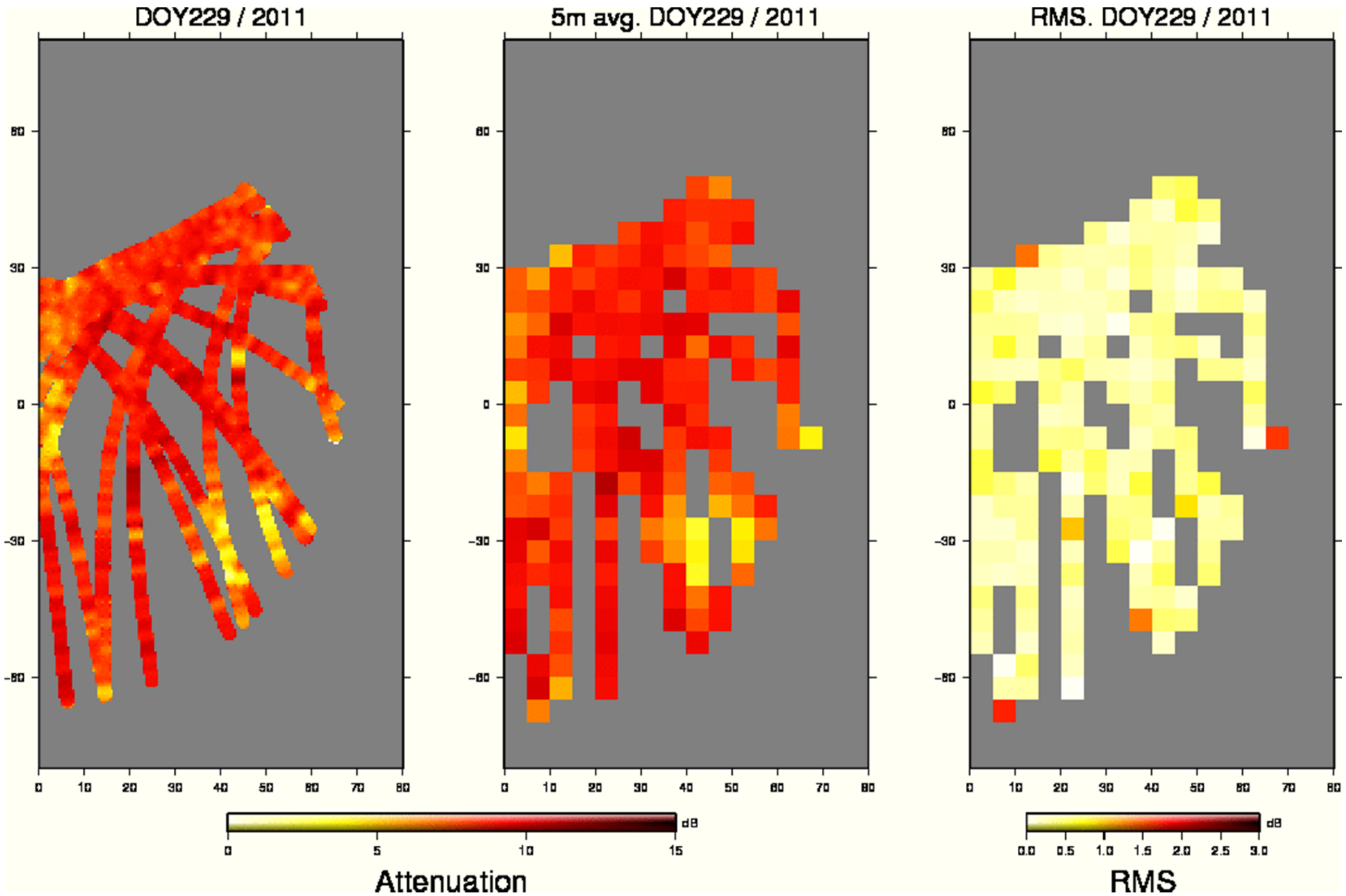
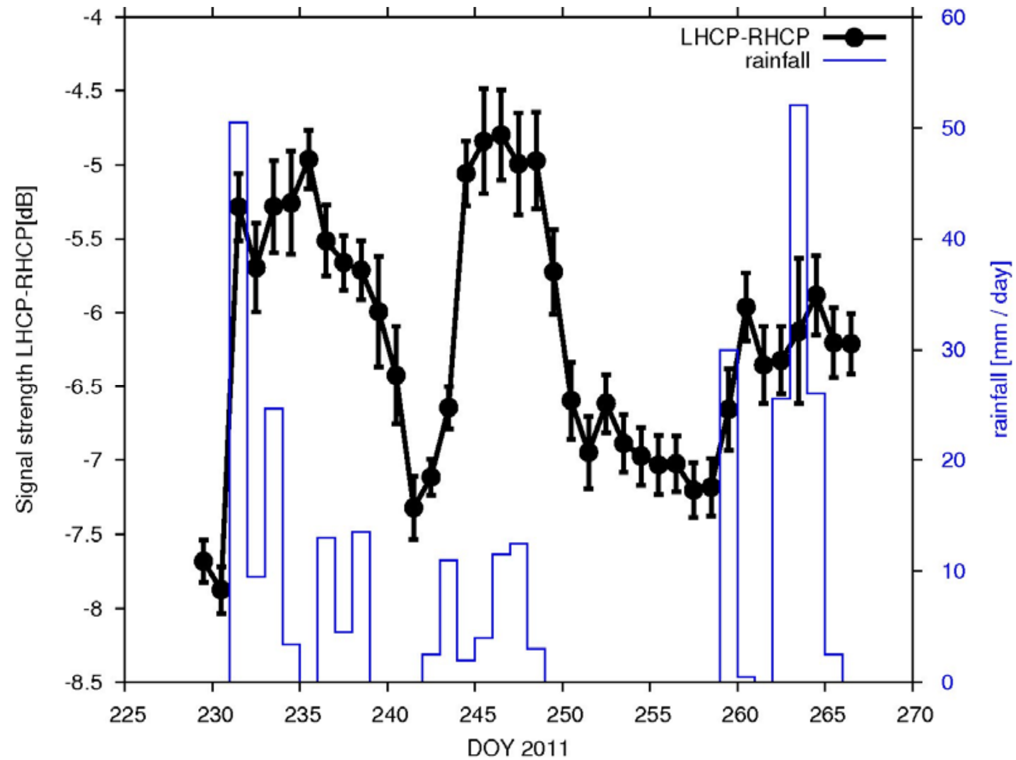
Example: 24h signal attenuation map (RHCP – LHCP)



Daily maps (animated)



Time-series extraction



Reflection strength correlates with rainfall rate
→ system is capable to remotely monitor soil moisture changes

Summary and outlook

- We developed and deployed a low-cost GNSS-R system based on software radio by making use of GPUs
- The system has been proven to be real-time operational
- First results confirm system concept
- We could already detect geophysical signals (soil moisture changes)
- Concept not limited to navigation satellite signals
- In the future we are going to carry out experiments on a site next the ocean (sea-level monitoring)

Thank you very much for your attention.

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