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LuMaMi – A fexible testbed for massive MIMO

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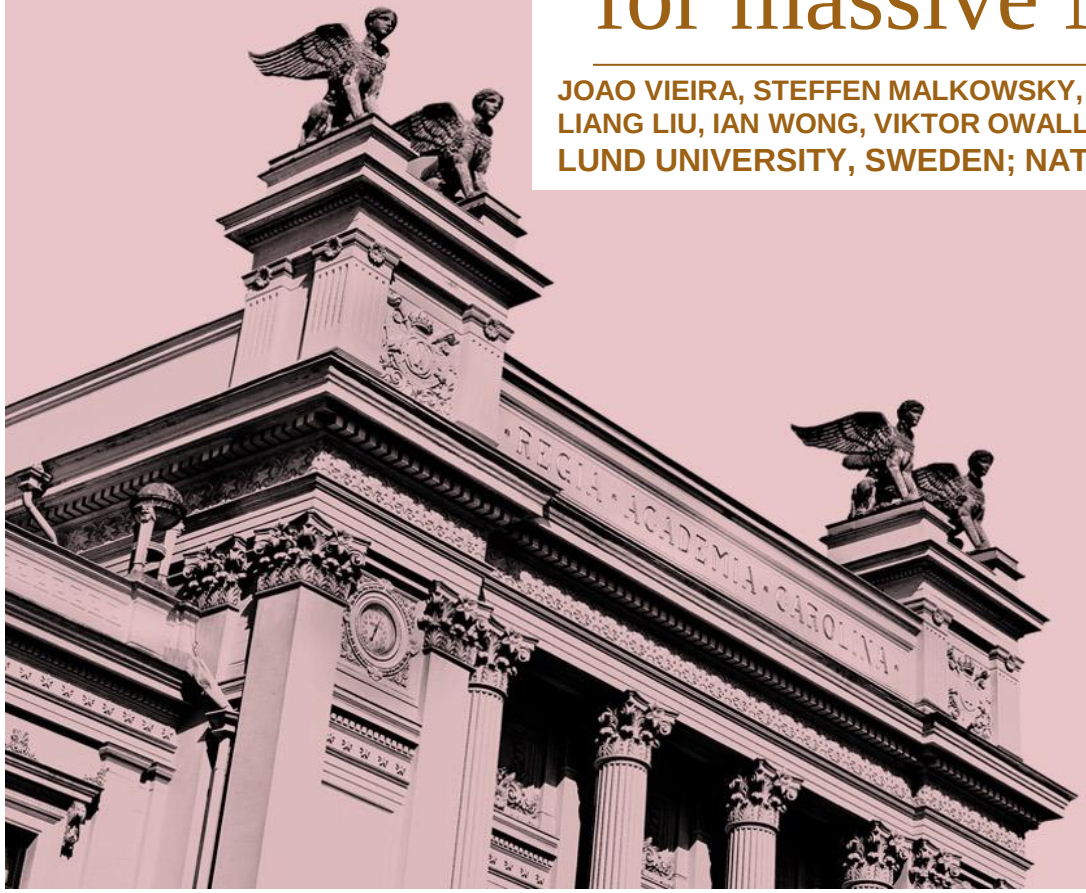

Massive MIMO research topics

- Propagation studies and channel modeling
- Antenna and antenna array design
- Baseband processing algorithms
- Baseband processing hardware
- System design and performance evaluations

We need a testbed to take the next step towards realizing massive MIMO.

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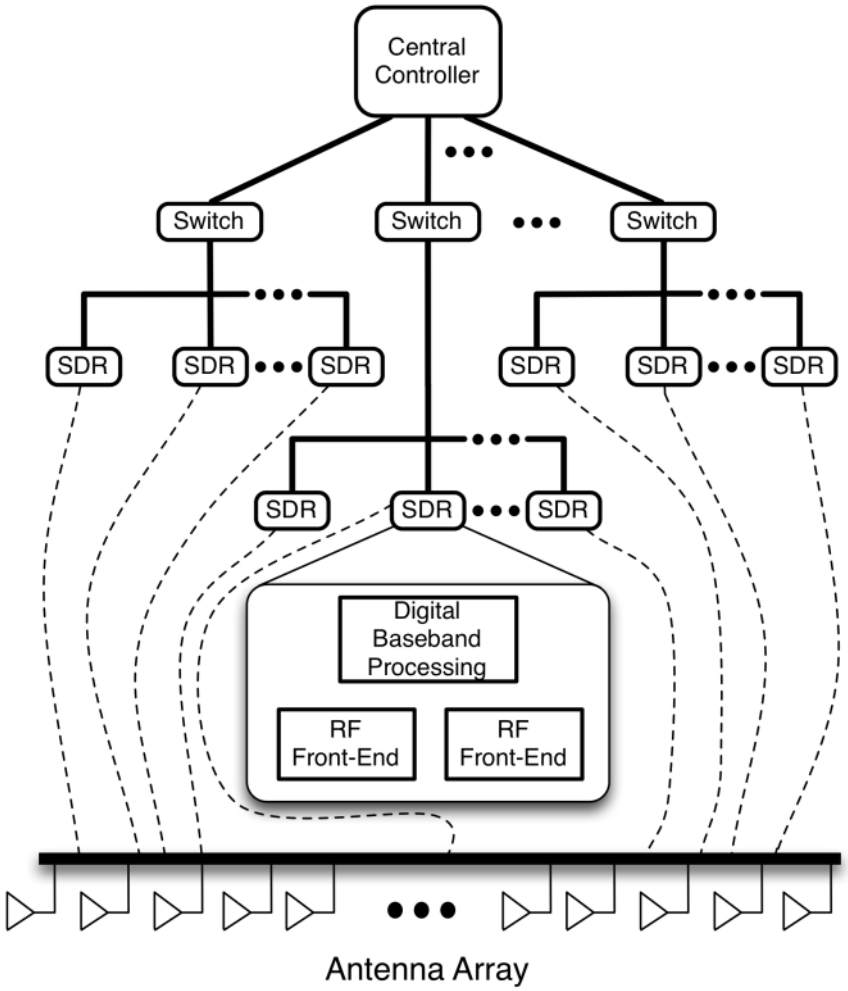
Challenges

- Coherency
  - the channel has to be constant between uplink and downlink
  - The 100 RF tranceivers have to be coherent and synchronous
- Reciprocity
  - The channel has to be reciprocal, including uplink and downlink tranceiver chains
- Data shuffling
  - 100 parallell RF chains generate data streams that have to be managed
- Baseband processing architecture
  - A combination of centralized and distributed processing.

System architecture



- Based on Star-Architecture
- Central Controlling Unit
  - Link Evaluation
  - Upper layer protocols
  - Logging data
  - Baseband Proc.
- Switches
  - Routing data
- SDR
  - Baseband Proc.
  - RF-Front End

System components

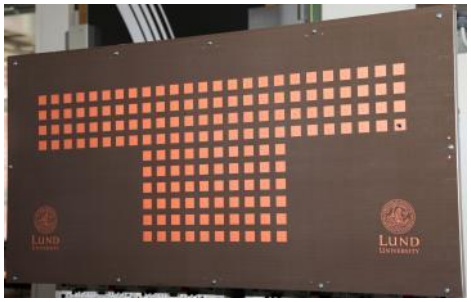
USRP 2943R

PXIe-1085 chassis

PXIe-8135 Controller

OctoClock-G

Printed antenna array

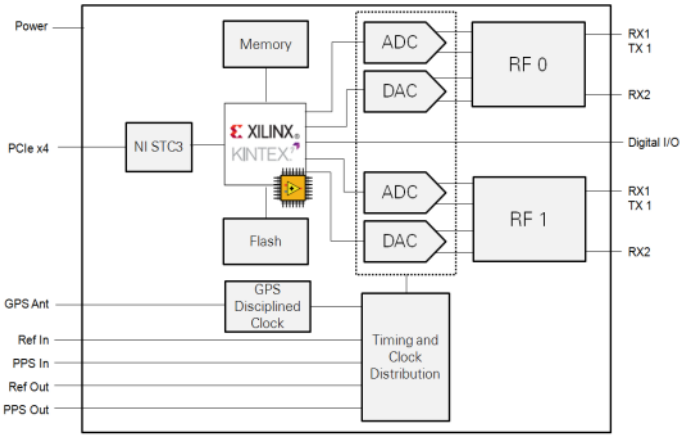


Flex RIO FPGA

System components - SDR

USRP RIO 2953R (Universal Software Radio Peripheral

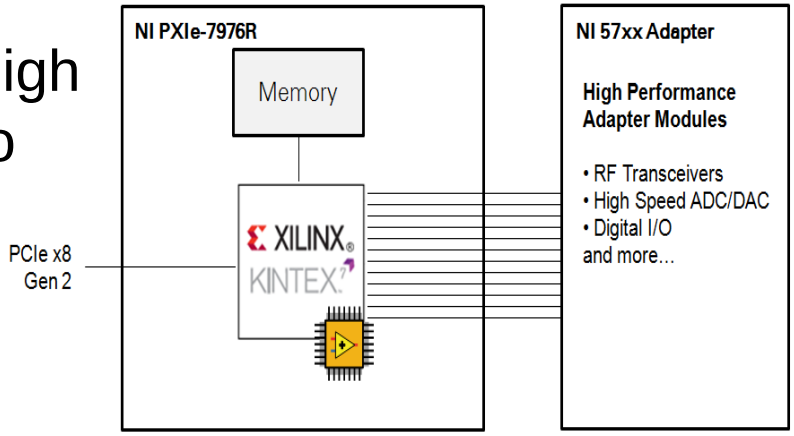
- 2 RF chains
- Xilinx Kintex-7 FPGA
- ~800 MBps bidirectional data streaming
- ~135 MBps baseband data
- Center frequency from 1.2 to 6 GHz



System components – FPGA coprocessor

FlexRIO 7976R (Flexible Reconfigurable Input Output)

- Xilinx Kintex-7 FPGA
- Up to 3.2 GBps data streaming
- Customizable I/O
- Up to 32 simultaneous high throughput connection to other FPGAs
- Used for centralized co-processing



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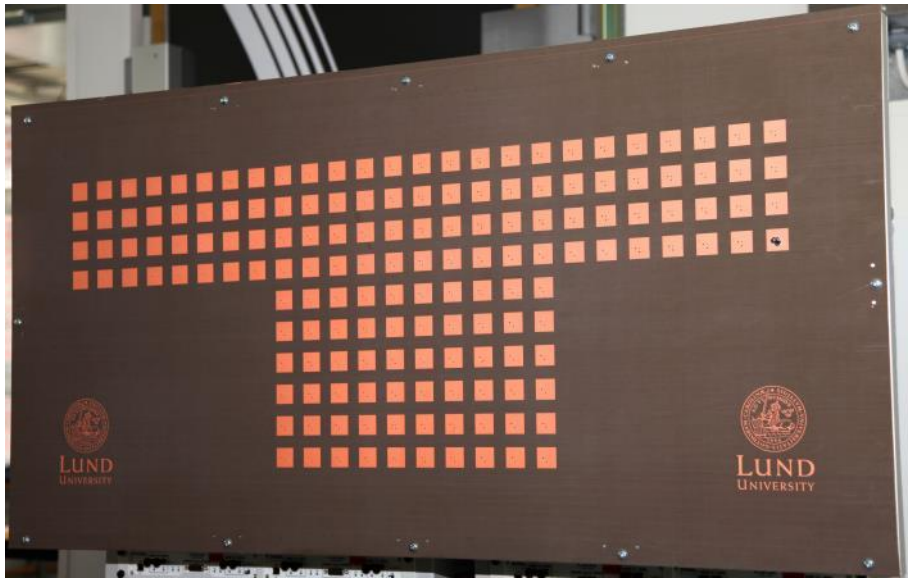
System components – Antenna Array



In-house design at Lund University

- Designed at the department for f_c = 3.7 GHz
- 10dB bandwidth of 183 MHz
- Average antenna match -28 dB.
- 160 dual polarized patch antenna array elements
- Allows different configurations
  - 4 x 25
  - 10 x 10
  - 5 x 10 dual pol.
  - etc …

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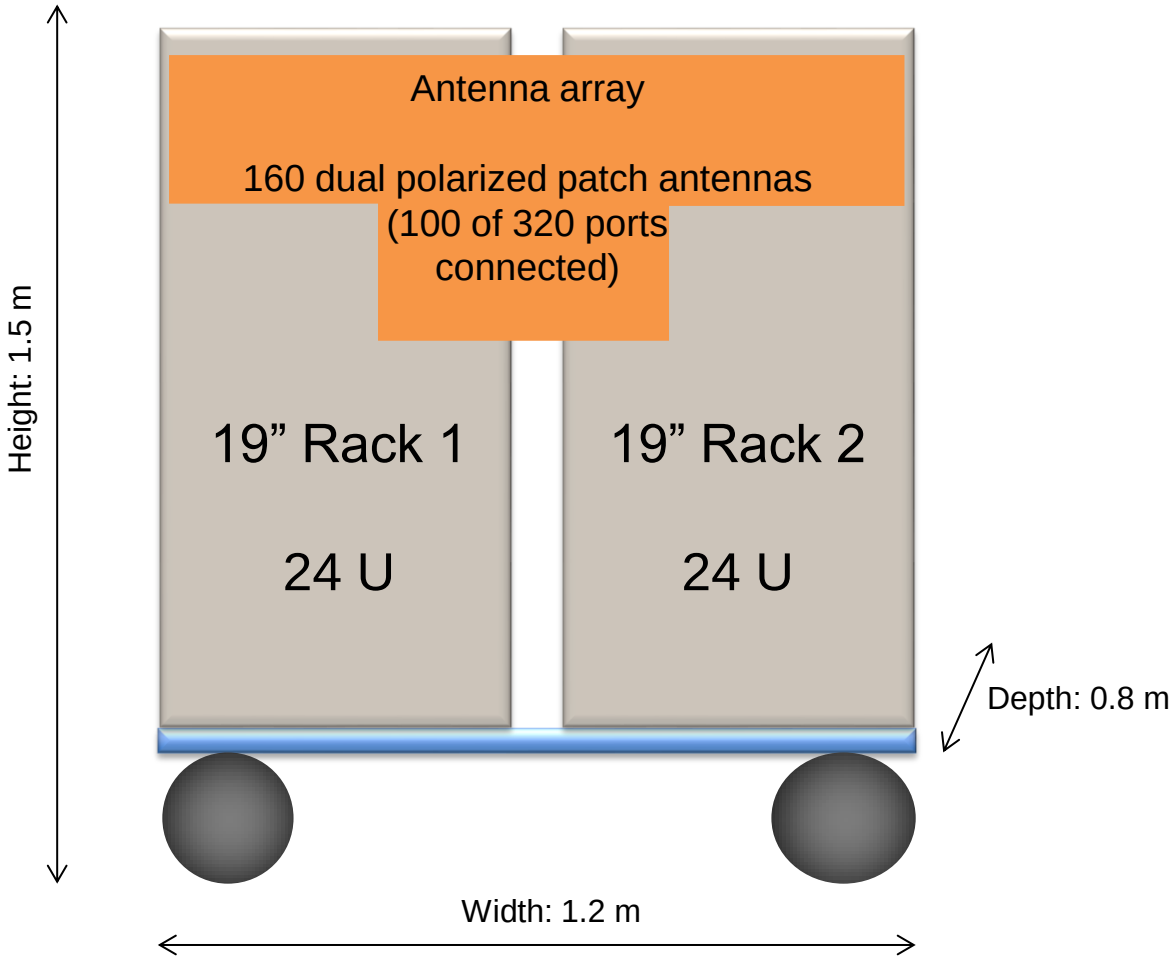
Assembly of ”mobile” base station



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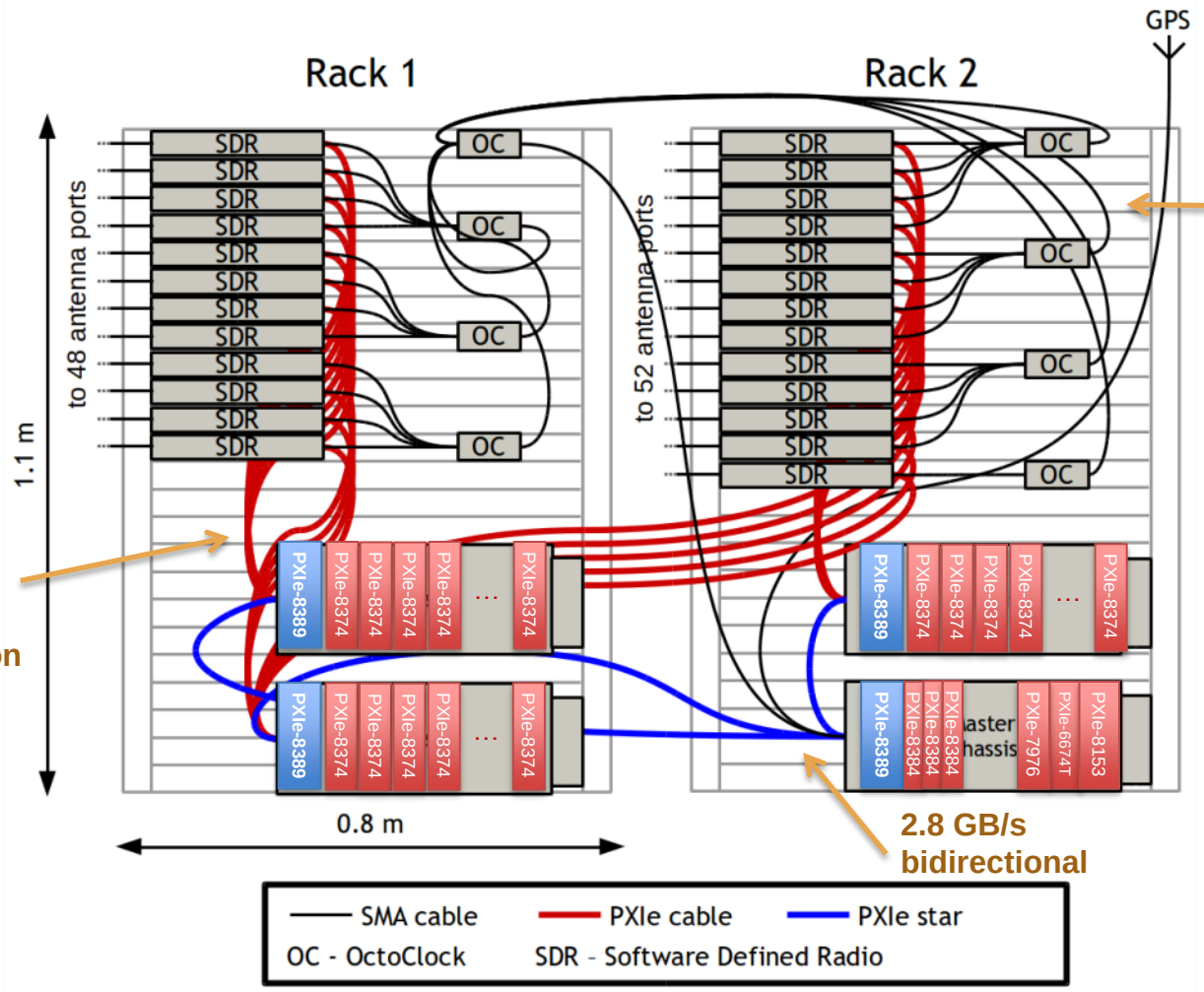
BS hardware setup: side-view

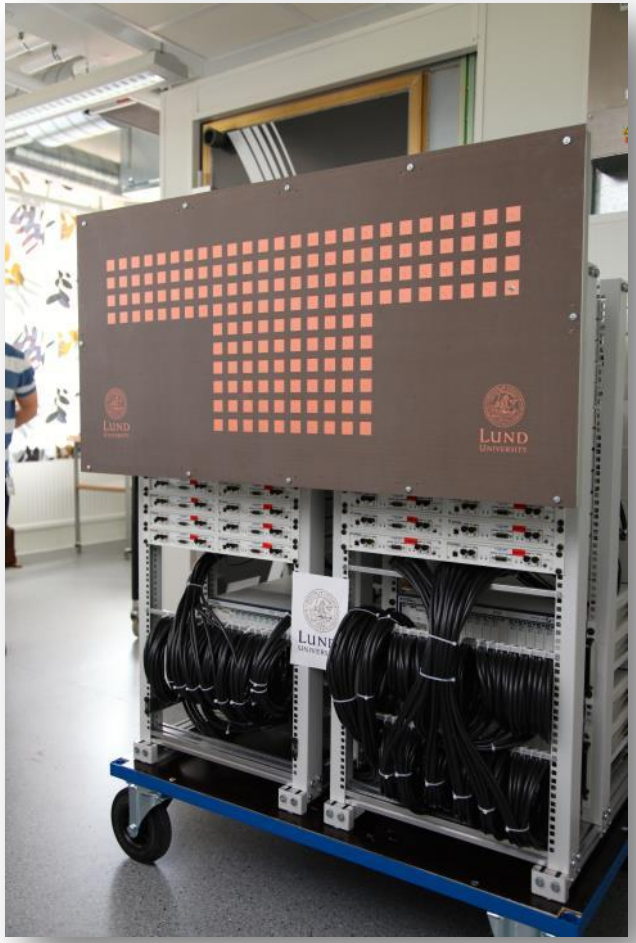


Time and Freq. synchonization network

Up to 800 MB/s/direction

2.8 GB/s bidirectional

Assembly of the base station



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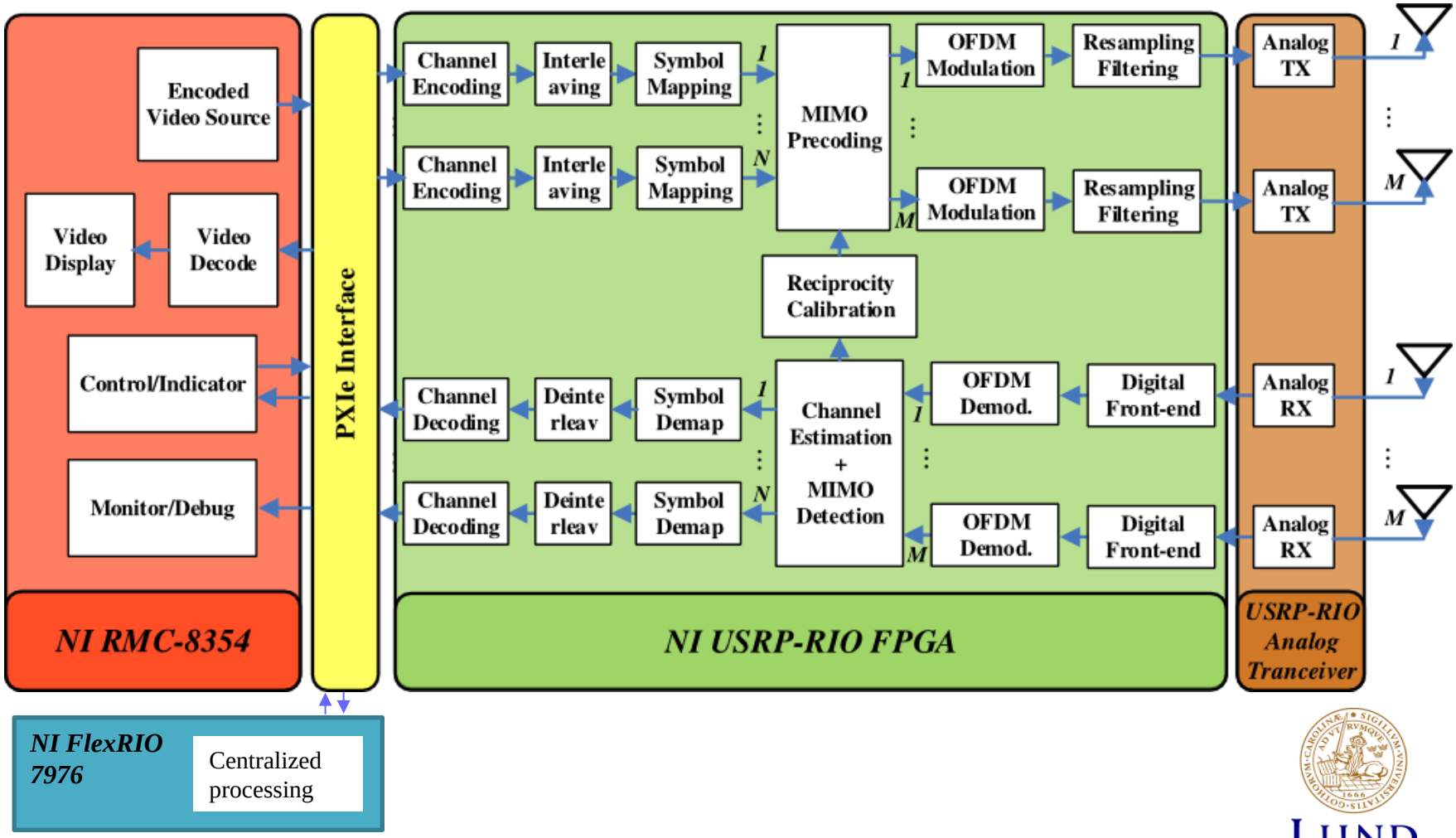
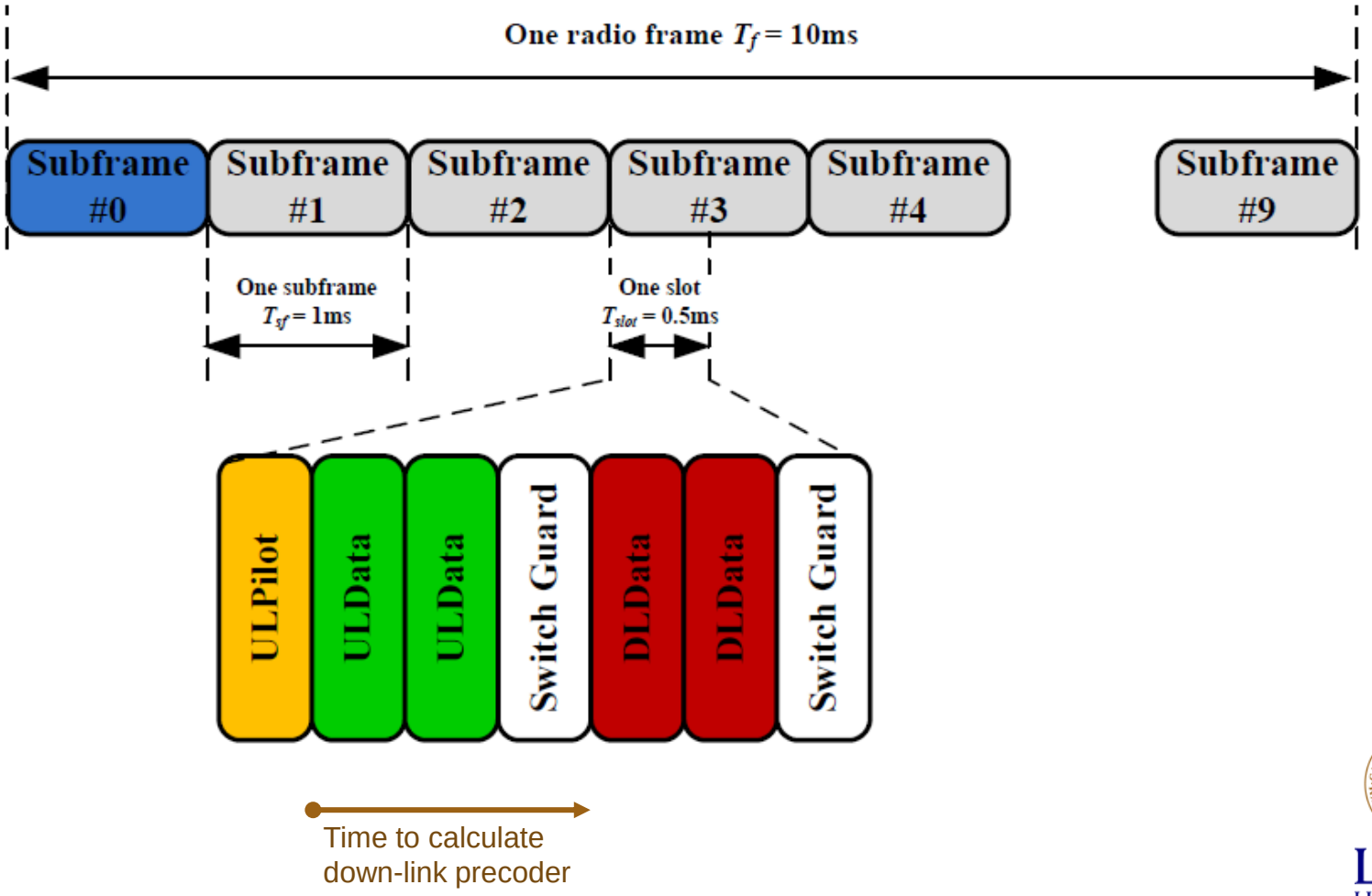
User-equipment

PXIe and OctoClock

Simplified processing block diagram
1st ver.: LTE-like OFDM-based TRX



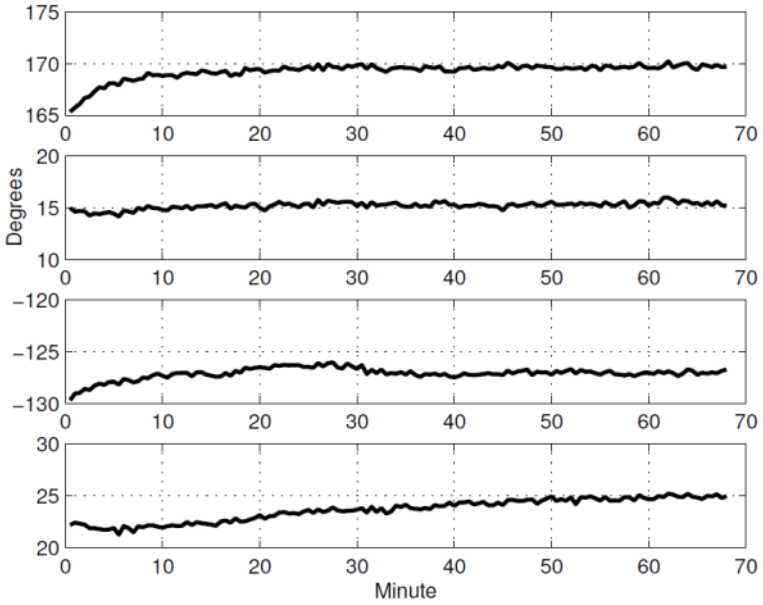
Basic frame structure



Initial results I

Capabilities of the RF front ends:

Phase coherence

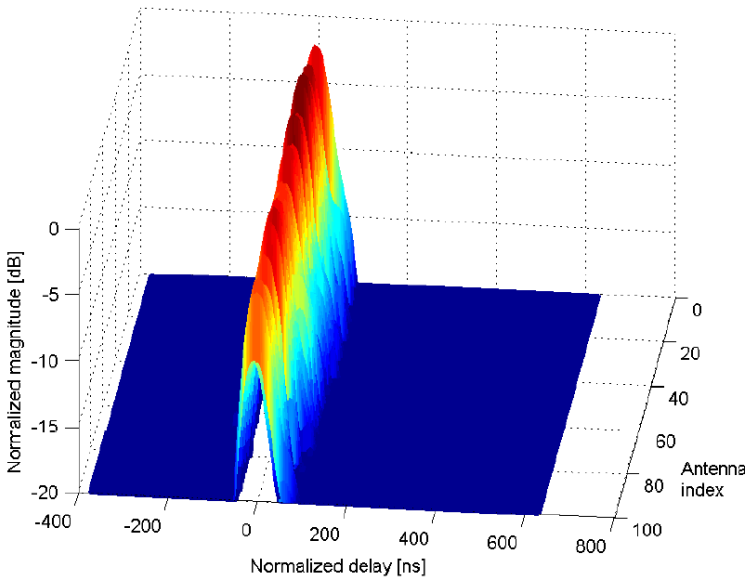


- Requirement: stable frequency response of RF-chains to achieve reciprocity calibration
- Transmit signal by one SDR and split into 4 other signals
- Fig. shows the phases of the received signals
- Only a few degrees of phase drift after warming up

Initial results II

Capabilities of the RF front ends:

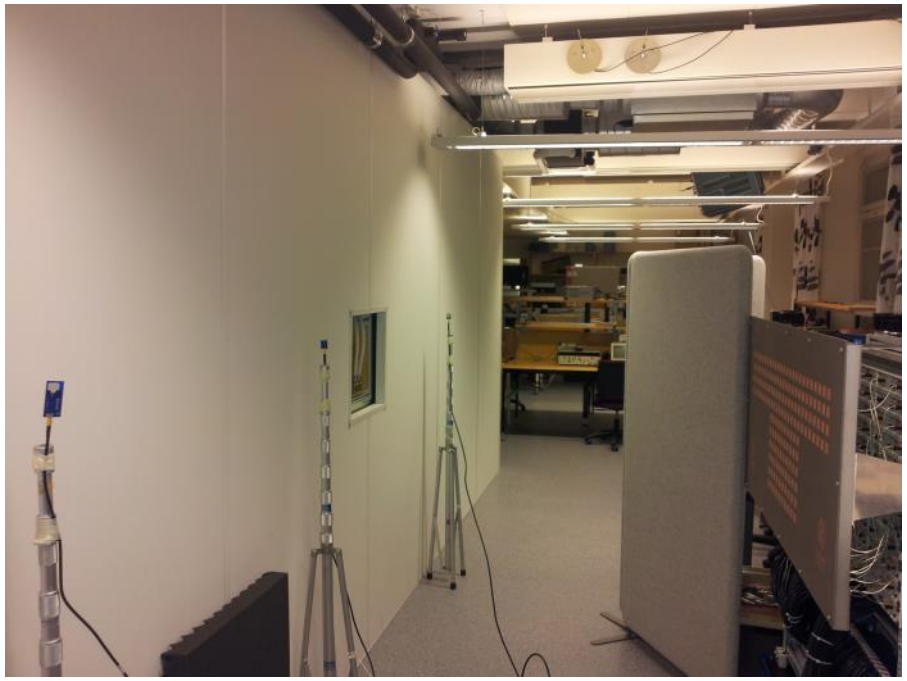
Time synchronization

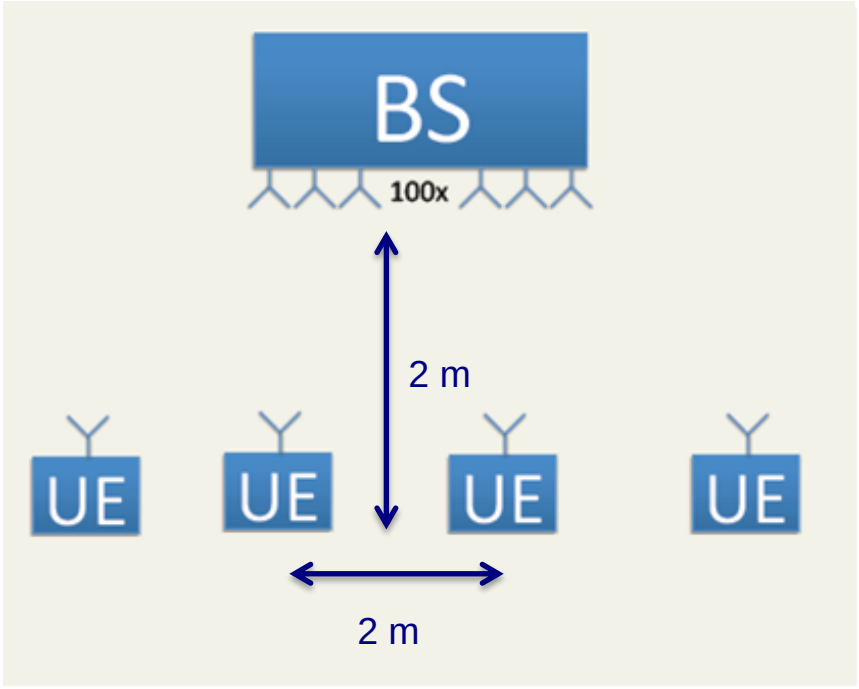


- 30.72 MHz i.i.d. Gaussian sequence transmitted by single antenna
- 25 x 4 Rx antenna aray with roughly same distance to Tx
- Strong LOS channel to verify sampling synchronization capabilities;
- Distinctive planar wavefront with a small delay spread;
- the received samples are time aligned within one 40 MS/s sample

Initial results

Received signal constellations – LOS & four users 2 m separation





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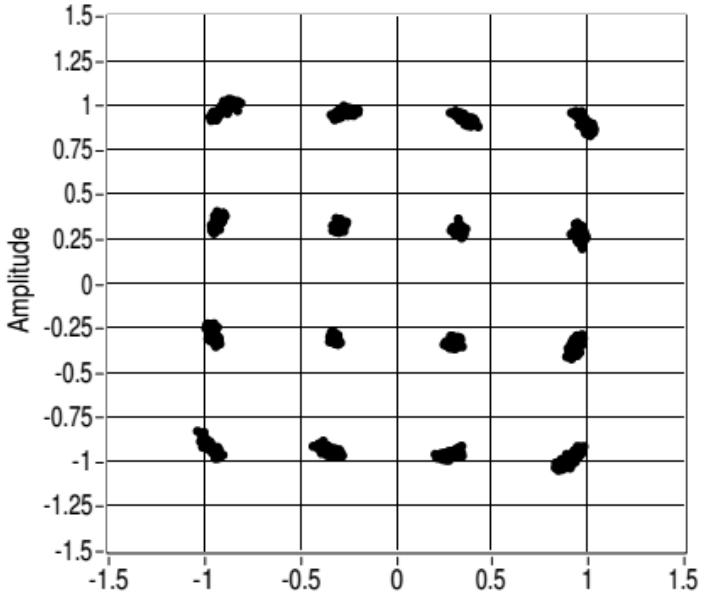
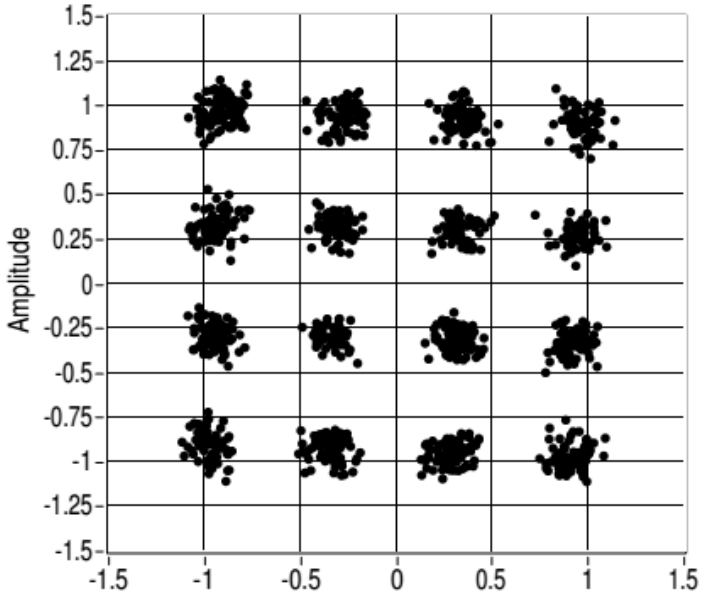
Initial results

Received signal constellations – LOS & four users 2 m separation

ZF detector

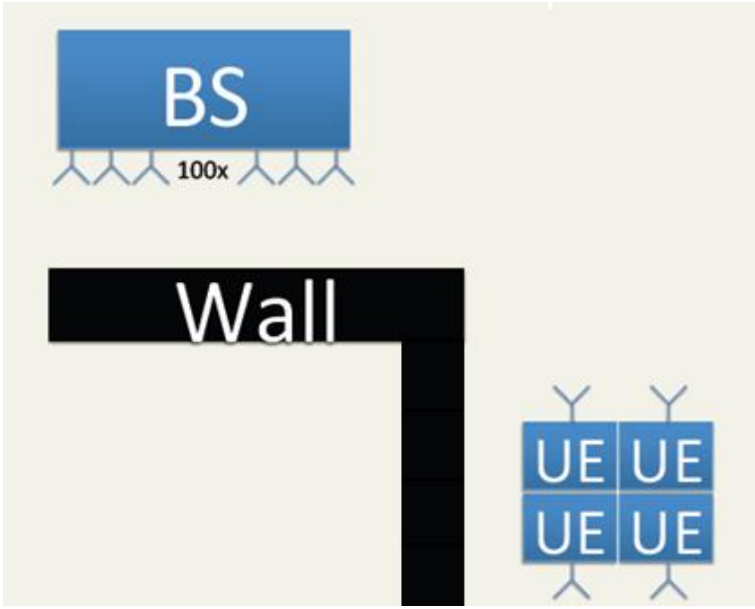


MRC detector



Initial results

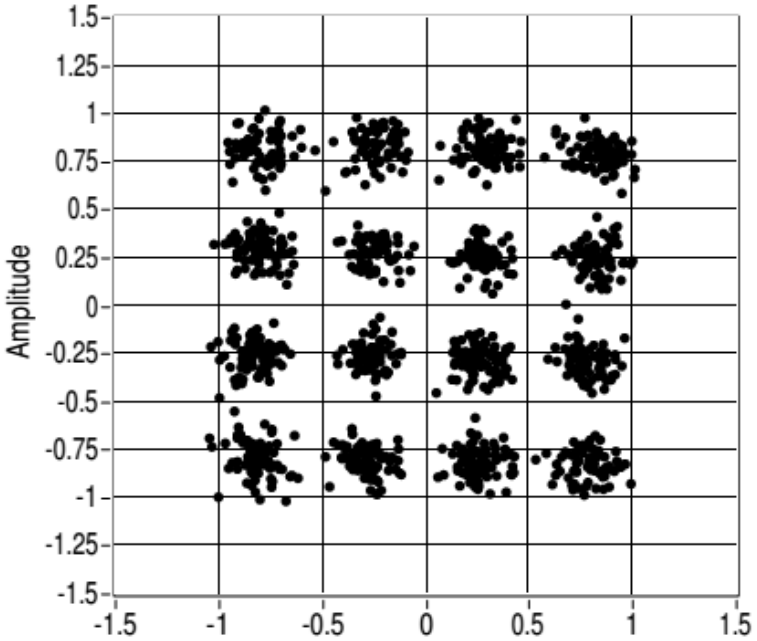
Received signal constellations – NLOS & four users in 15 cm radius



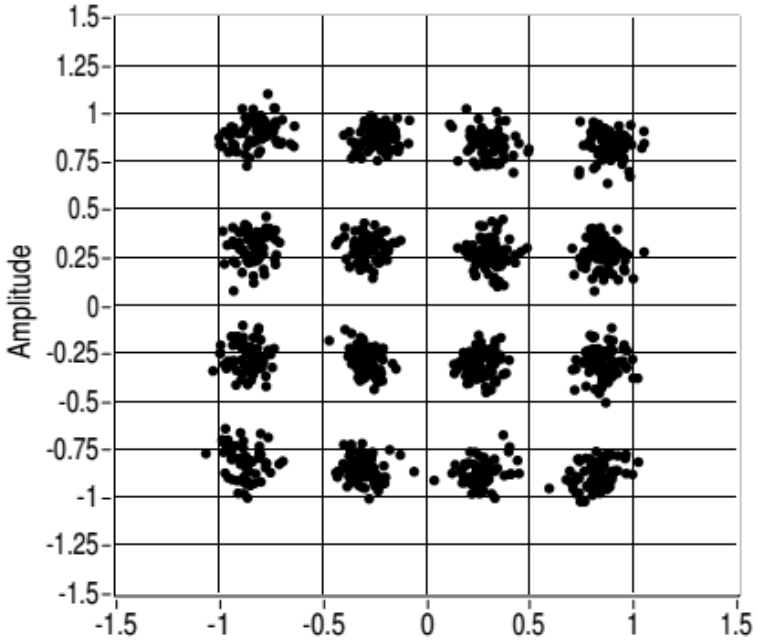
Initial results

Received signal constellations – NLOS & four users in 15 cm radius

User 1 – ZF detector



User 2 – ZF detector



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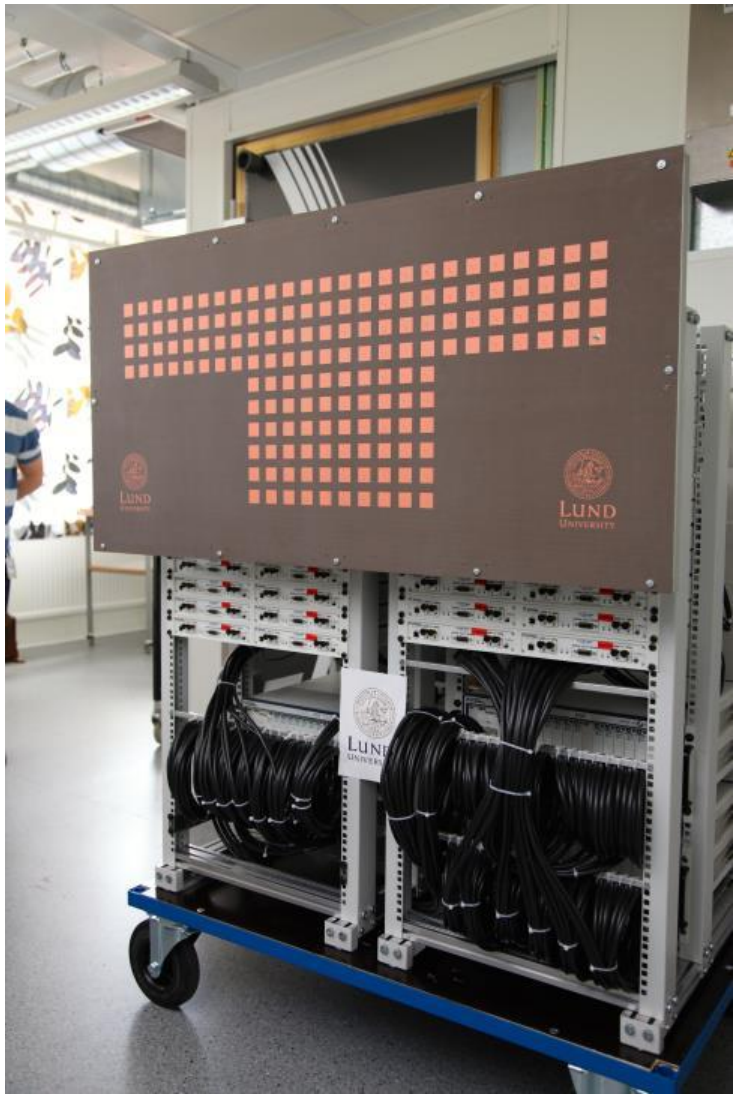
Summary



- 100 coherent RF chains
- Flexible architecture based on NI platform and software radios
- Supports 10 simultaneous single antenna users in the *same* time-frequency resource block
- Real time operation in the 3.7 GHz band, 20 MHz bandwidth
- Taking Massive MIMO from the lab to reality.

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