LuMaMi - Lund University Massive MIMO testbed

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Testbed Challenges

- Large amount of baseband data
  - 100 Ant. * 4 byte for I/Q * 30.72 MS/s ~ 100Gbps
- Synchronization of RF front ends
  - Octoclock
- Processing latency
  - Find suitable frame structure
- Reciprocity calibration
  - RF chains not reciprocal
  - Calibration scheme required
- First testbed of this size worldwide

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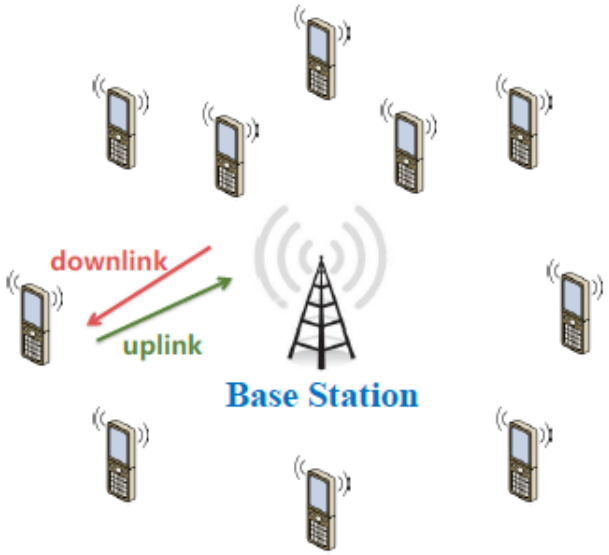
Testbed used for ...

1) High speed data streaming for multiple users

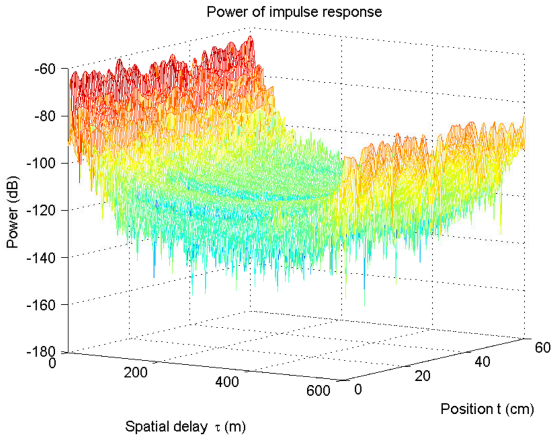


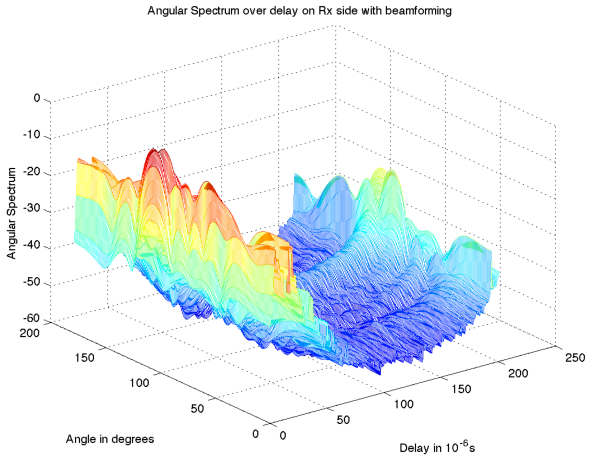
- 10 mobile users stream HD video on uplink to basestation
- Basestation streams 10 HD videos on downlink to users.

Testbed used for ...

1) High speed data streaming for multiple users

2) Channel sounding





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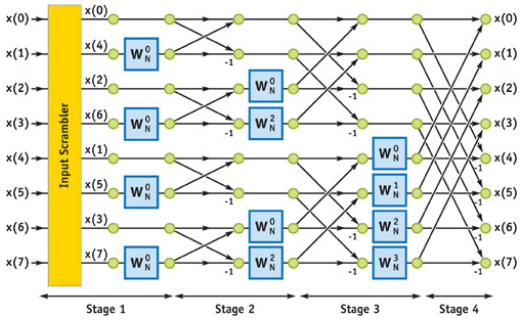
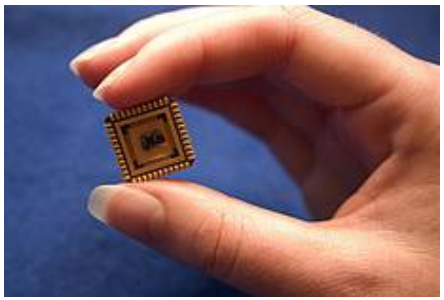
Testbed used for ...

1) High speed data streaming for multiple users
2) Channel sounding
3) Evaluation of baseband solutions (algorithms and architectures)



Testbed used for ...

1) High speed data streaming for multiple users
2) Channel sounding
3) Evaluation of baseband solutions (algorithms and architectures)
4) Assisting circuit design



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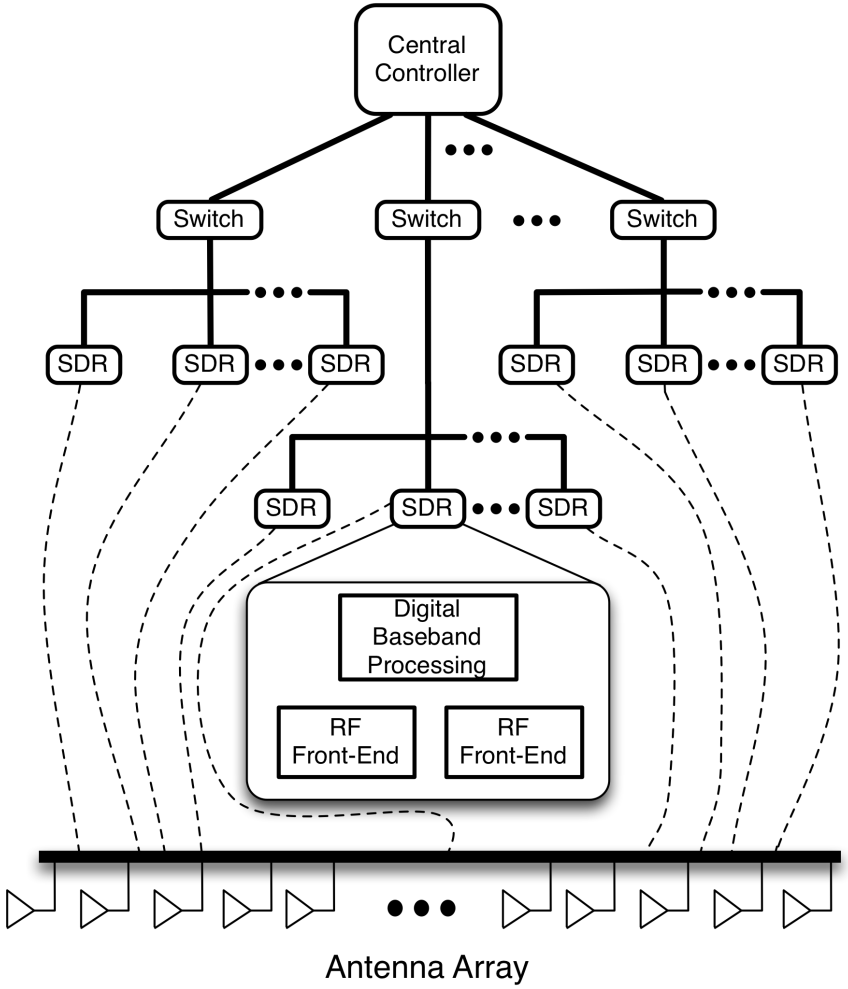
General Overview



- 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

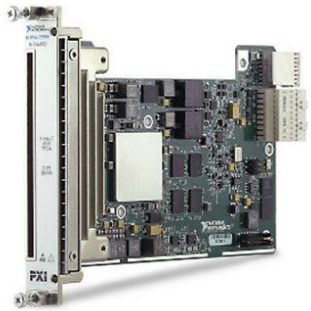
System components - Overview

SDR

Chassis

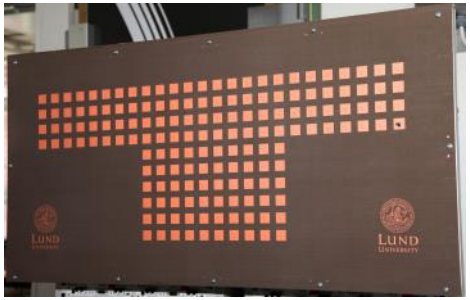
Central Controller

FPGA coprocessor



OctoClock

Printed antenna array



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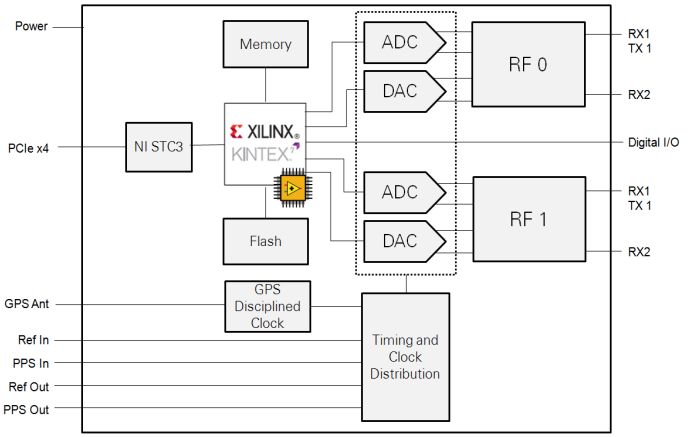
System components - SDR

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



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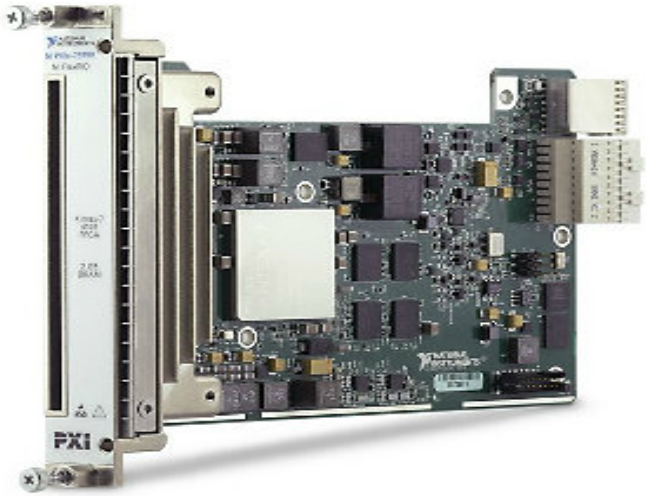
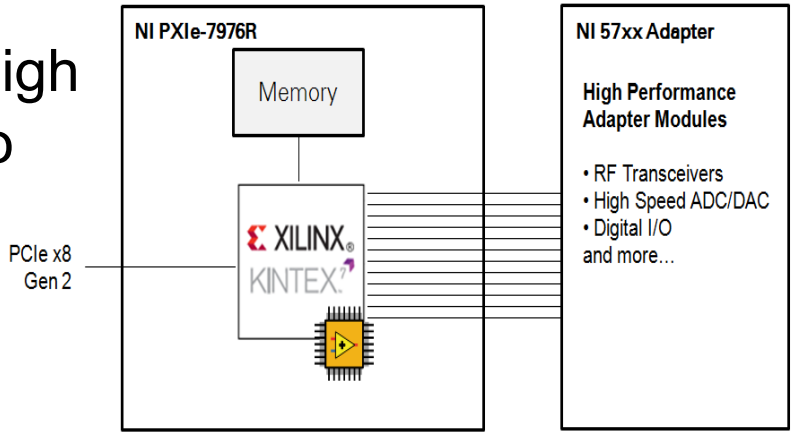
System components – FPGA coprocessor

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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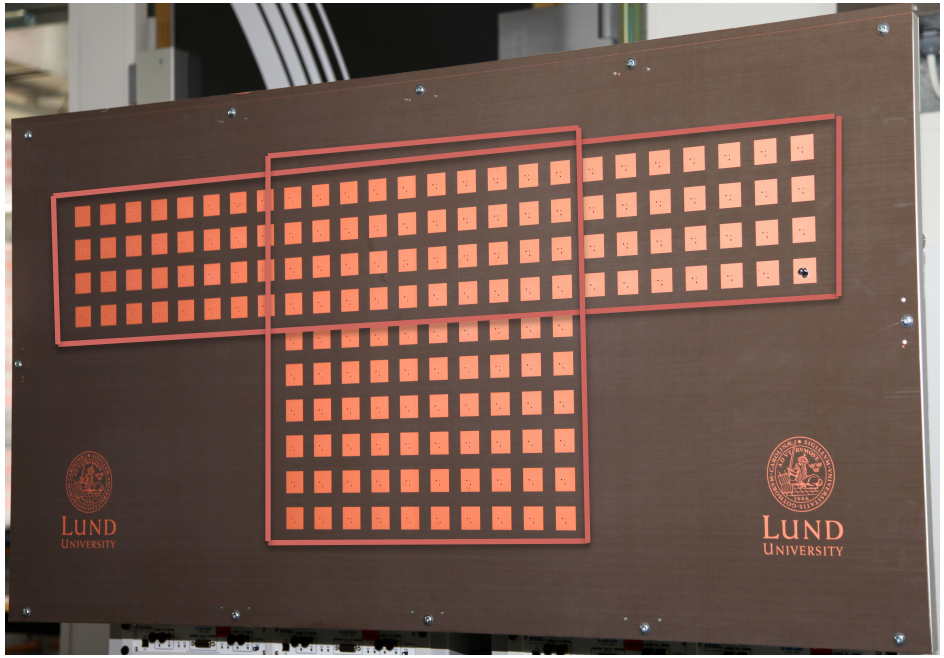
System components – Antenna Array



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

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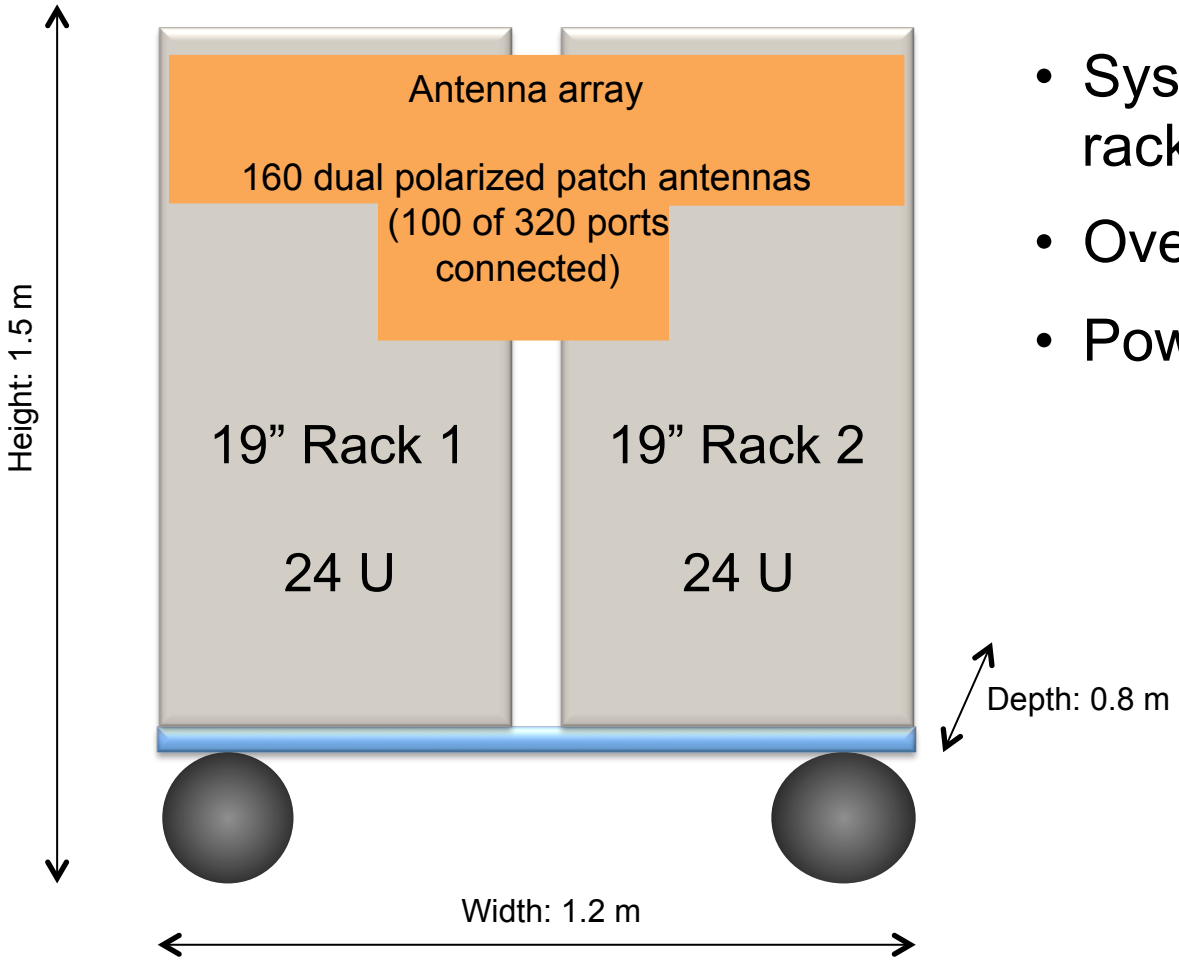
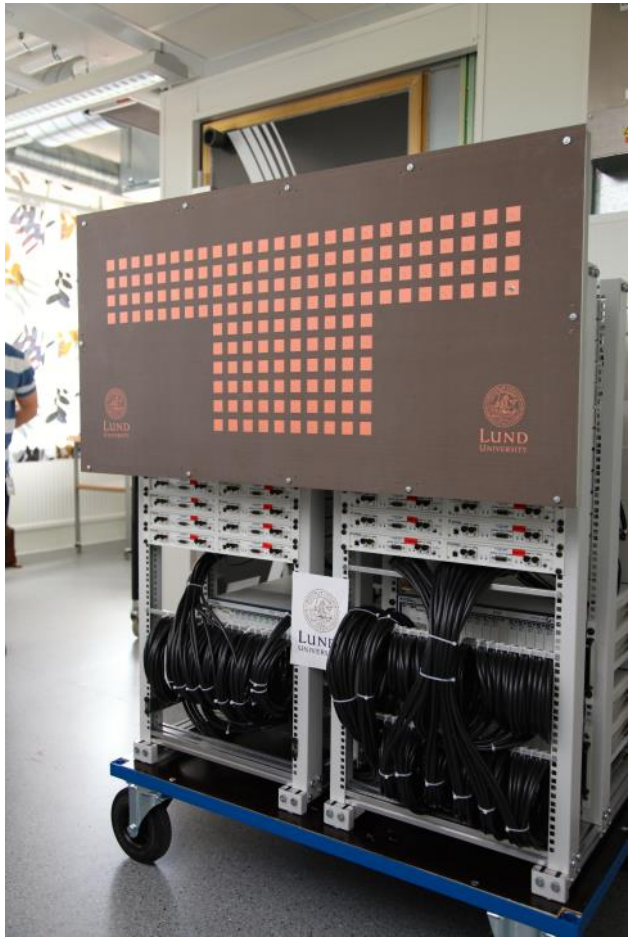
Assembly of ”mobile” base station



- System mounted on rollable rack
- Overall weight: 300 kg
- Power consumption: 2.5 kW

1st Version Assembly



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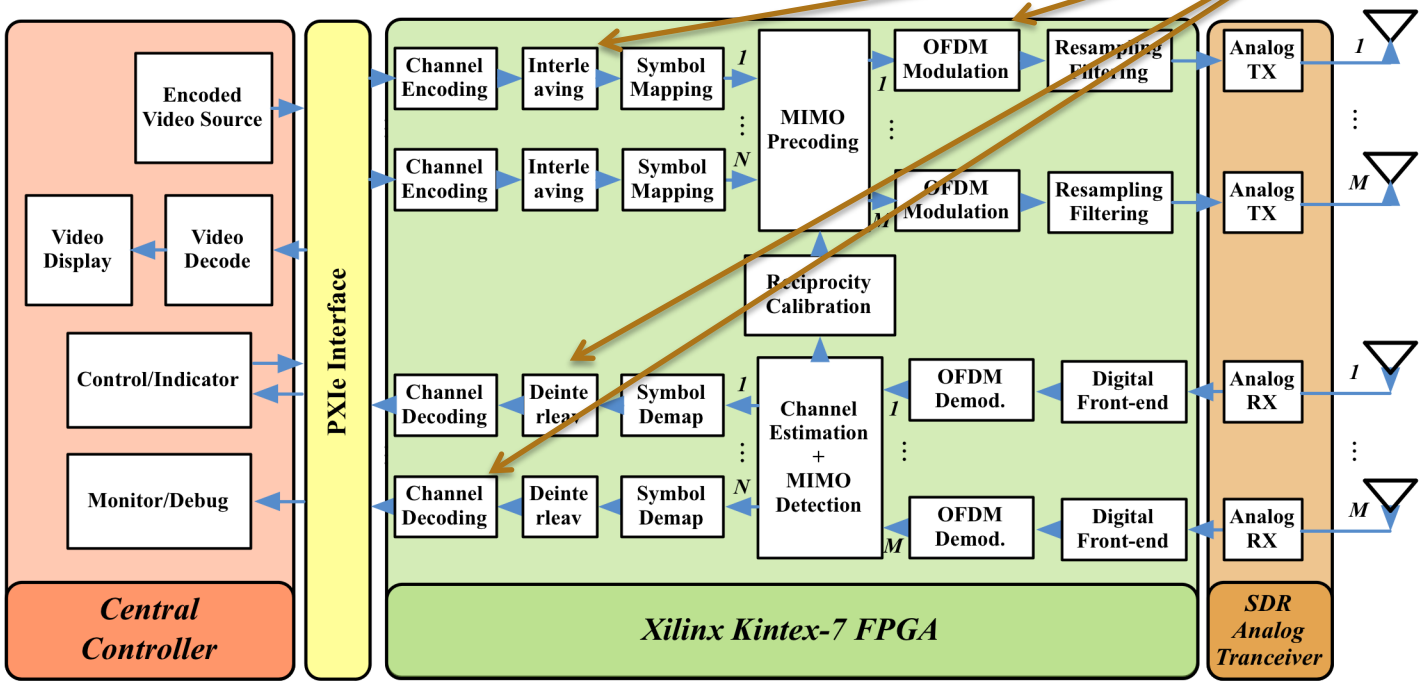
1st version LTE-like OFDM-based massive MIMO transmission

Parameter	Variable	Value
Bandwidth	W	20 MHz
Carrier frequency	f_c	3.7 GHz
Sampling Rate	F_s	30.72 MS/s
FFT Size	N_{FFT}	2048
# Used subcarriers	N_{used}	1200
Slot time	T_S	0.5 ms
Sub-Frame time	T_{sf}	1 ms
Frame time	T_f	10 ms
# UEs	K	10
# BS antennas	M	100

Thank you Xilinx for donating IP blocks



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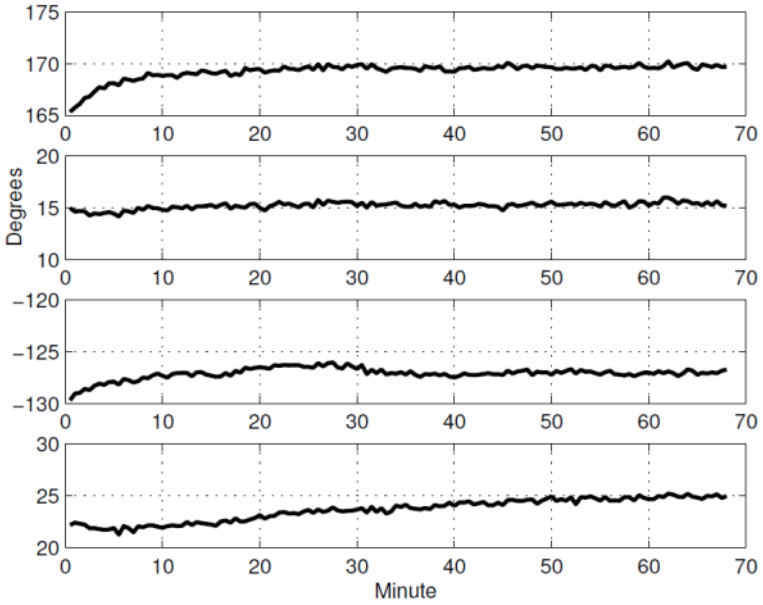
Initial results I

Capabilities of the RF front ends:

Phase coherence

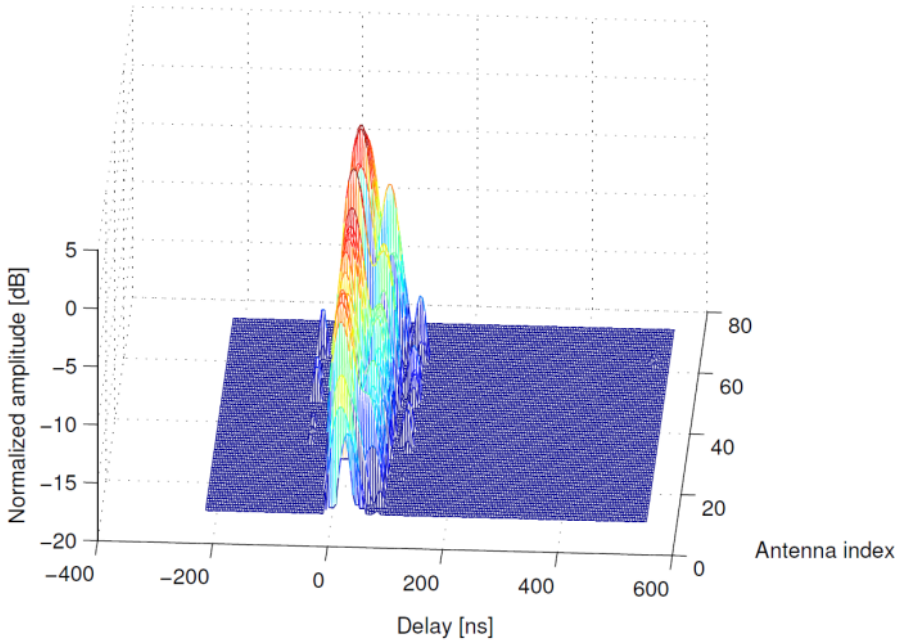


- Requirement: stable frequency response of RF-chains to achieve reciprocity calibration
- Transmit signal by one SDR and split into 4 other signals
- Fig. shows the phases of the received signals
- 5 degree drift during 1 hour of measurements

Initial results II

Capabilities of the RF front ends:

Time synchronization



- 40 MHz Gaussian PN sequence transmitted by single antenna
- 16 x 4 Rx antenna subset 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 MHz sample

Ongoing Work

- **Short term goal**:
  - A demonstration of massive MIMO at the uplink using MR and ZF combiners
- **Long term goals**:
  - Implementation of uplink/downlink frame structure, reciprocity calibration, etc, for uplink/downlink transmission
  - Reduced/no PAR, precoders
  - Establish performance boundaries for practical Massive MIMO systems