Parallel Channel Sounder for MIMO Communications

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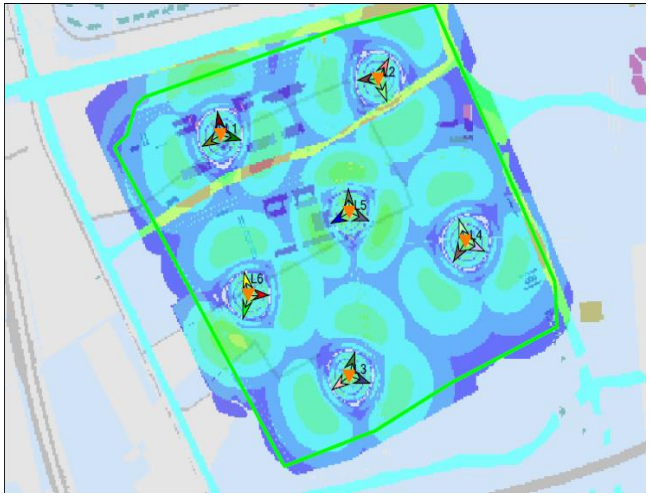
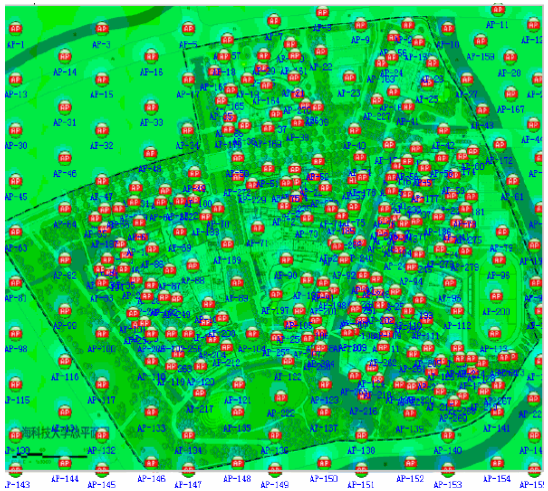
About our our lab

- **WiCO:** R&D on Communication Technology
- **SHIFT:** R&D on Fog Computing (combination of IT and CT)
- **SIMIT:** R&D on Internet of Things

ShanghaiTech University



LTE+5G macro-cell BSs



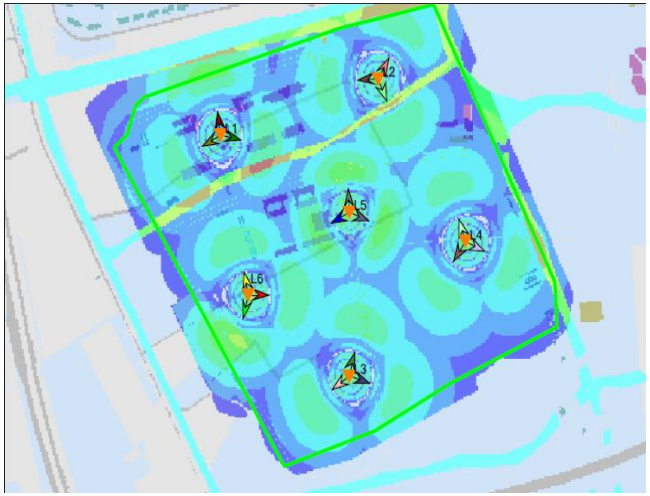
Outdoor APs

About our our lab

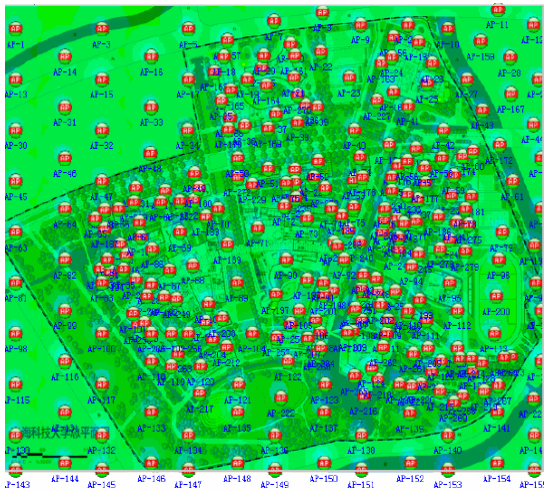
- **LTE + 5G hierarchical network architecture**
  - 6 macro-cell base stations
  - 10~20 micro-cell base stations
  - 100+ small base stations
  - Trial of GPP-based BSs

- **802.11ac high speed WLAN**
  - 100~200 outdoor APs
  - 1000~10000 indoor APs
  - UDN, multi-carriers
  - Trial of GPP-based APs

ShanghaiTech University



LTE+5G macro-cell BSs



Outdoor APs

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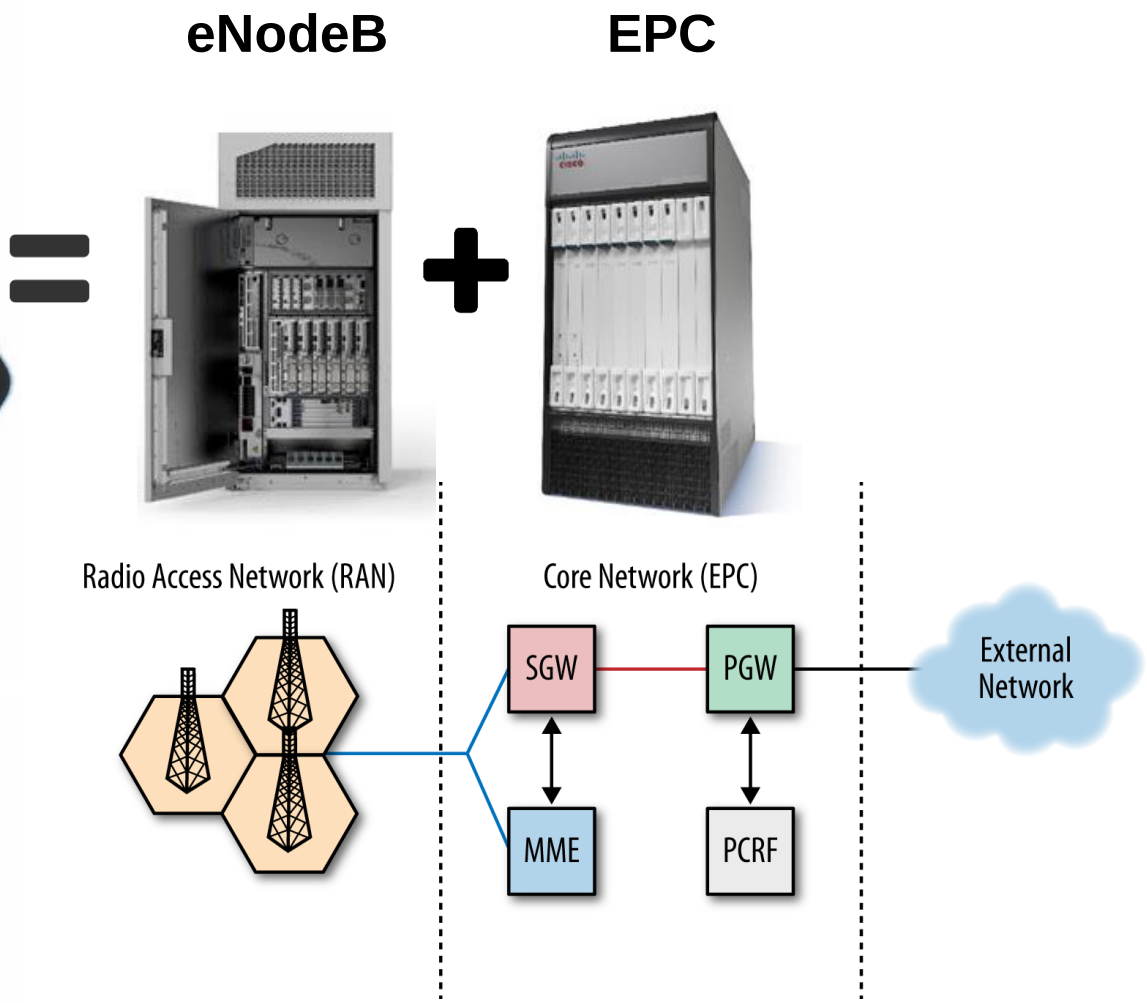


Outline

- Motivations
- System Design and Implementation
- Key Technologies
- Future Work

Channel Modeling is important for Wireless Communications

VANET

High-speed Train

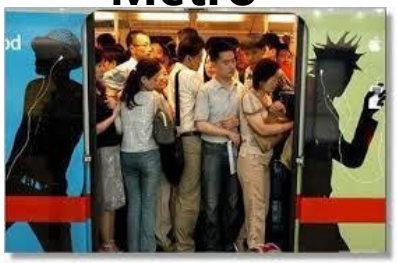
Aircraft

Industry

Residential area

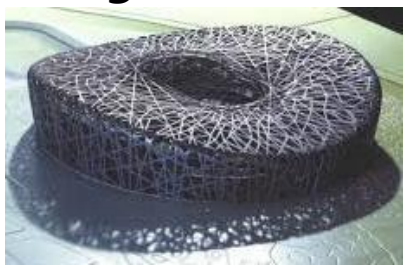
Office

Metro



Public place

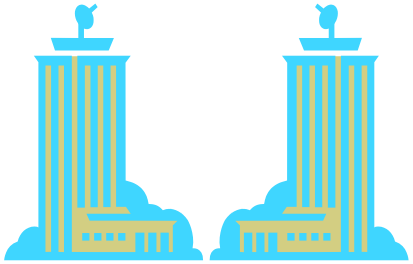
Large stadium



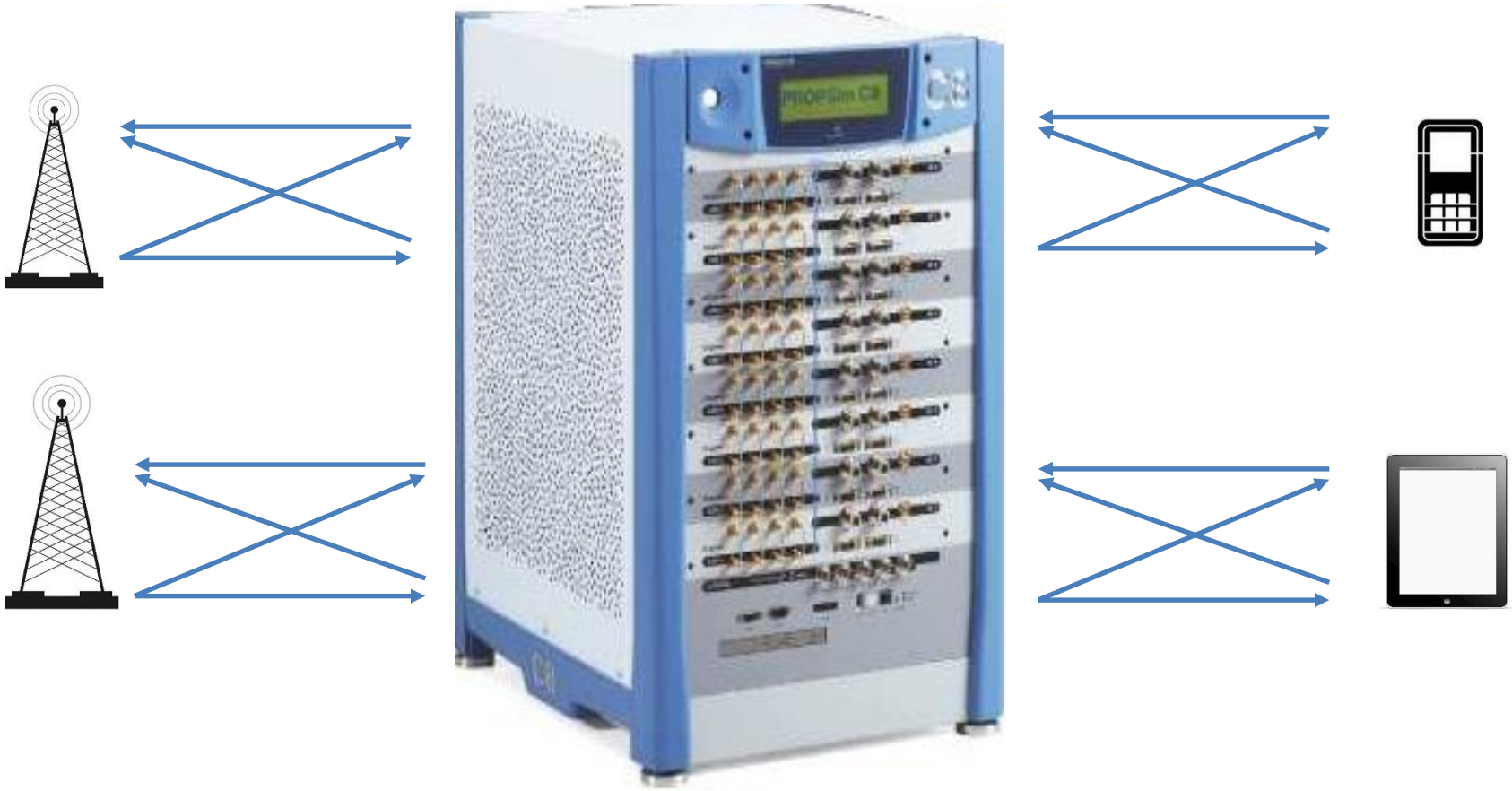
Suburb

Highrise

Backhaul



Channel Emulator to facilitate R&D on Physical Layer Algorithms



What have been done?

Channel Sounder

Data Sharing Platform

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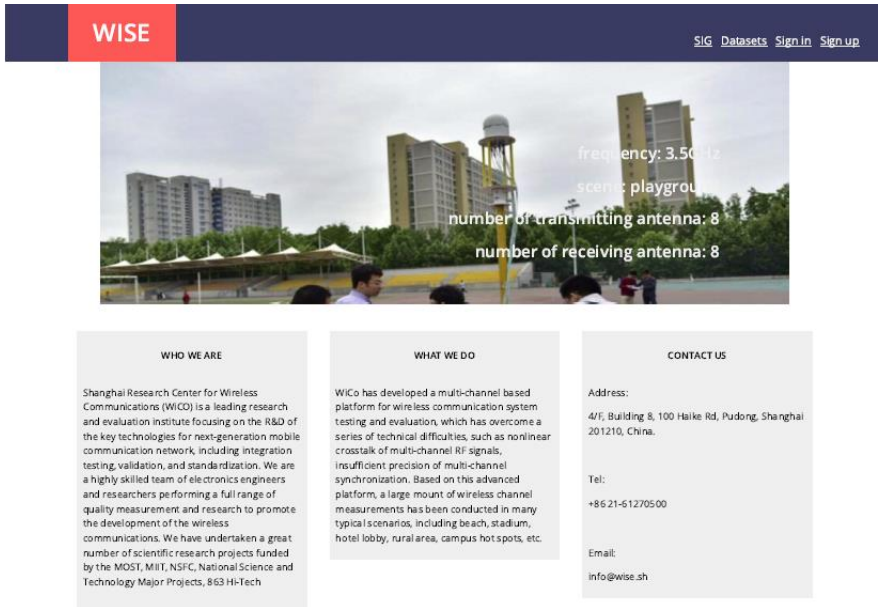

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System Design Requirement

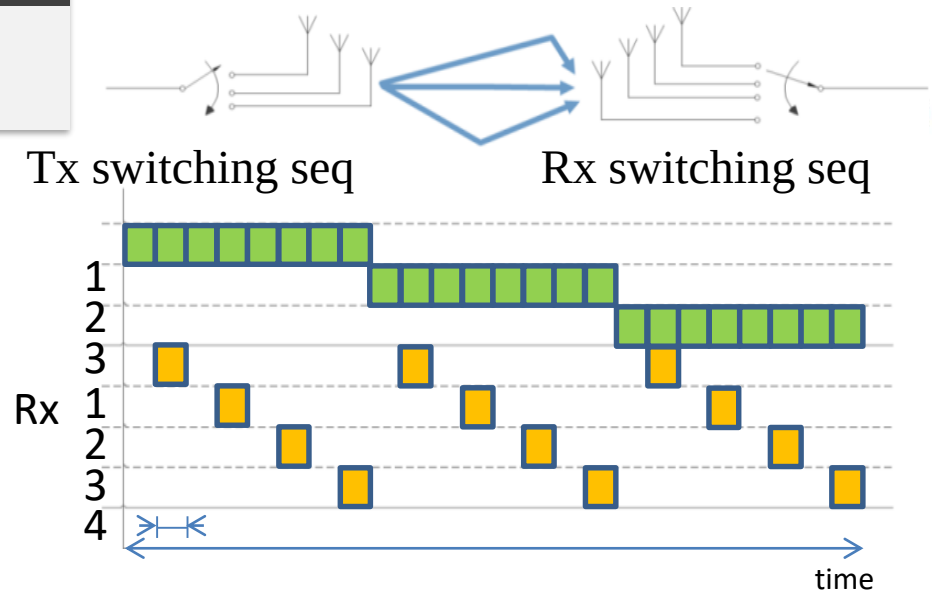
1. Scenarios: Distance >500m; 3D channel; Speed (350km/h).

2. High-precision synchronization between multiple channels

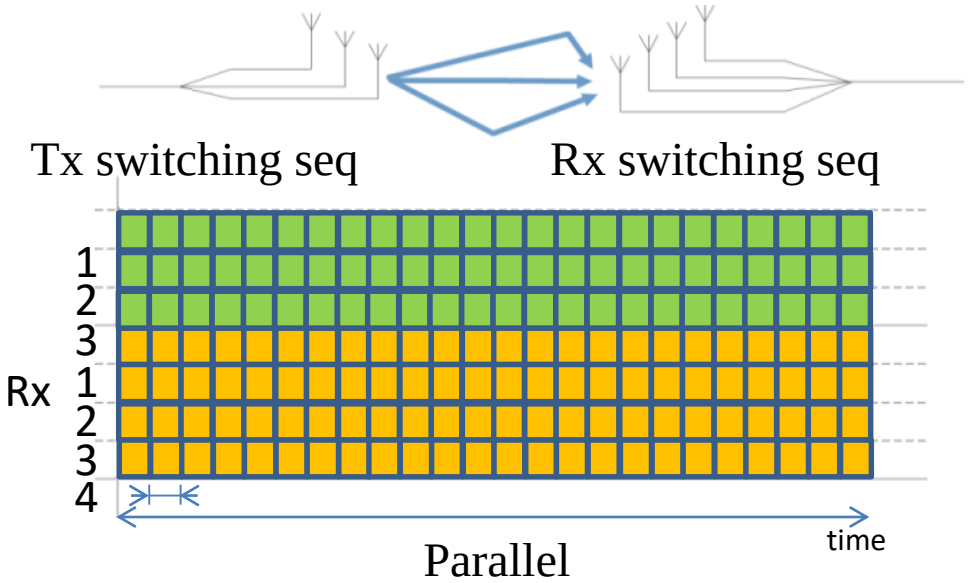
3. Raw data real-time storage

4. Calibration for MIMO transceiver: 64 channels and vector signal transceiver system response

5. Post data processing for multichannel: interference cancellation and parameter estimation



TDM

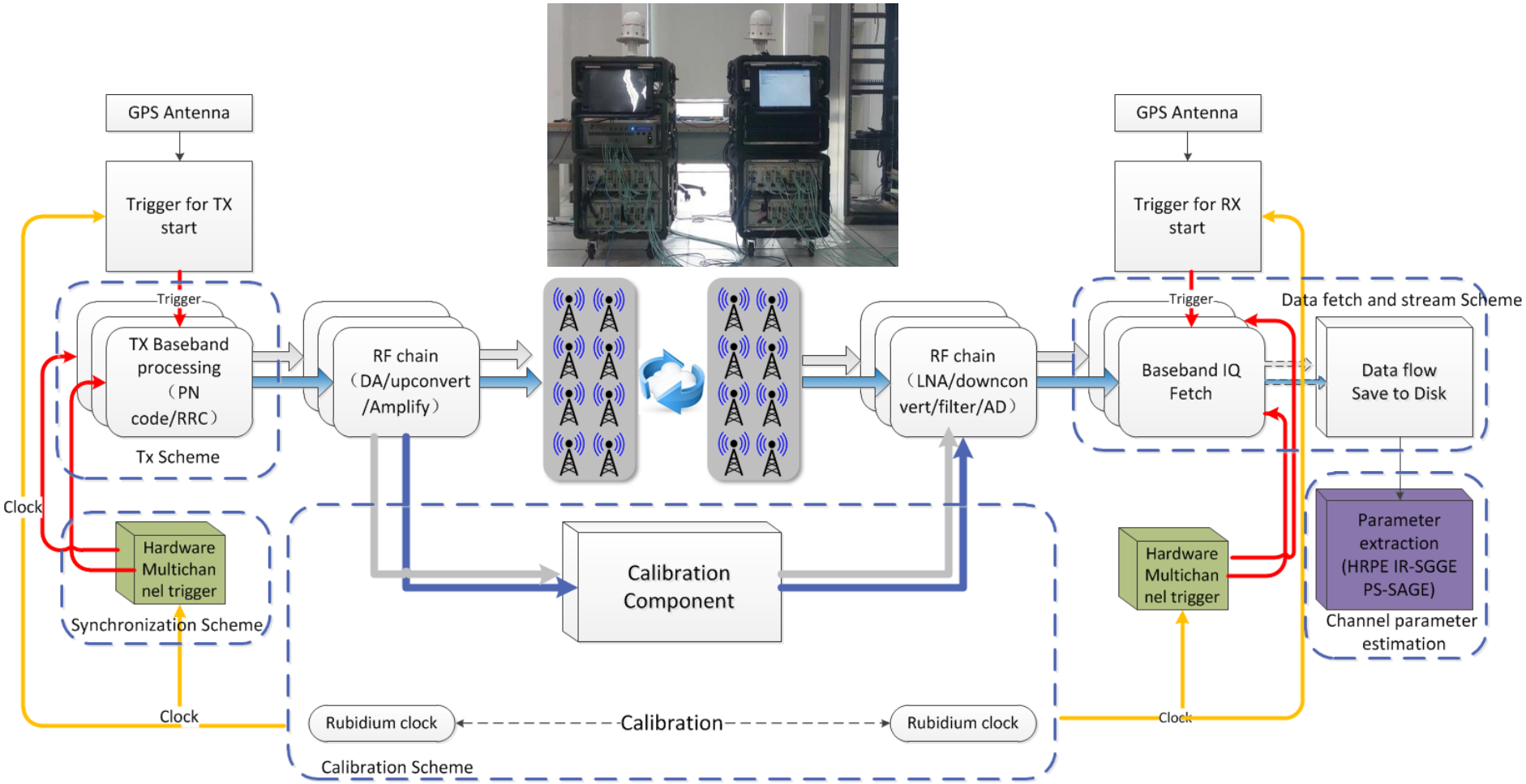


Parallel

System Design Requirement

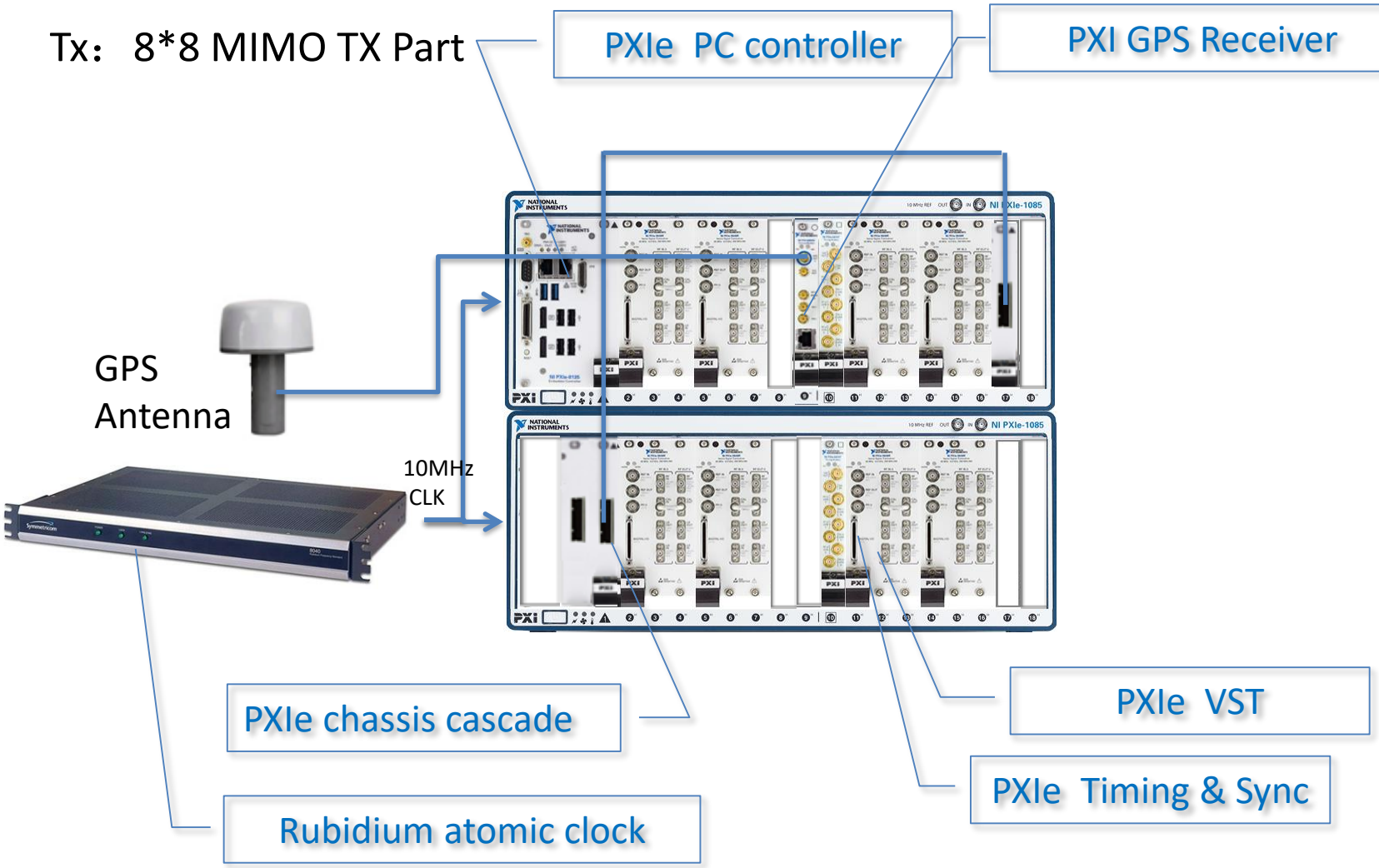
ID	Function/Parameter	Value
1	Multi-channel 8×8 bidirection	/
2	Frequency range（without PA）	200MHz-5.9GHz
3	Frequency range（with PA）	2.1GHz-5.9GHz
4	Phase error of time base signal	≤ 5ns
5	Transmit Power （Each Channel）	≤8W
6	Overall Power Consumption （Transmitter& Receiver）	≤ 3KW
7	IQ rate of Transmitter（Each Channel）	Max 250MS/s
8	IQ rate of Receiver（Each Channel）	Max 250MS/s
9	System bandwidth	Max 200MHz(±5MHz)
10	Phase error of each channel （Transmitter）	≤ 50ps
11	GPS Location Function（Transmitter& Receiver）	/
12	System Calibration Function	/
13	Data transfer rate & storage capacity	≤ 3.2GB/s & 5TB
14	Delay resolving precision	0.4×1/Bandwidth
15	Dynamic range of CIR	30dB
16	Max duration of data streaming	≥25min
17	Characteristic parameter extraction	/

System Framework



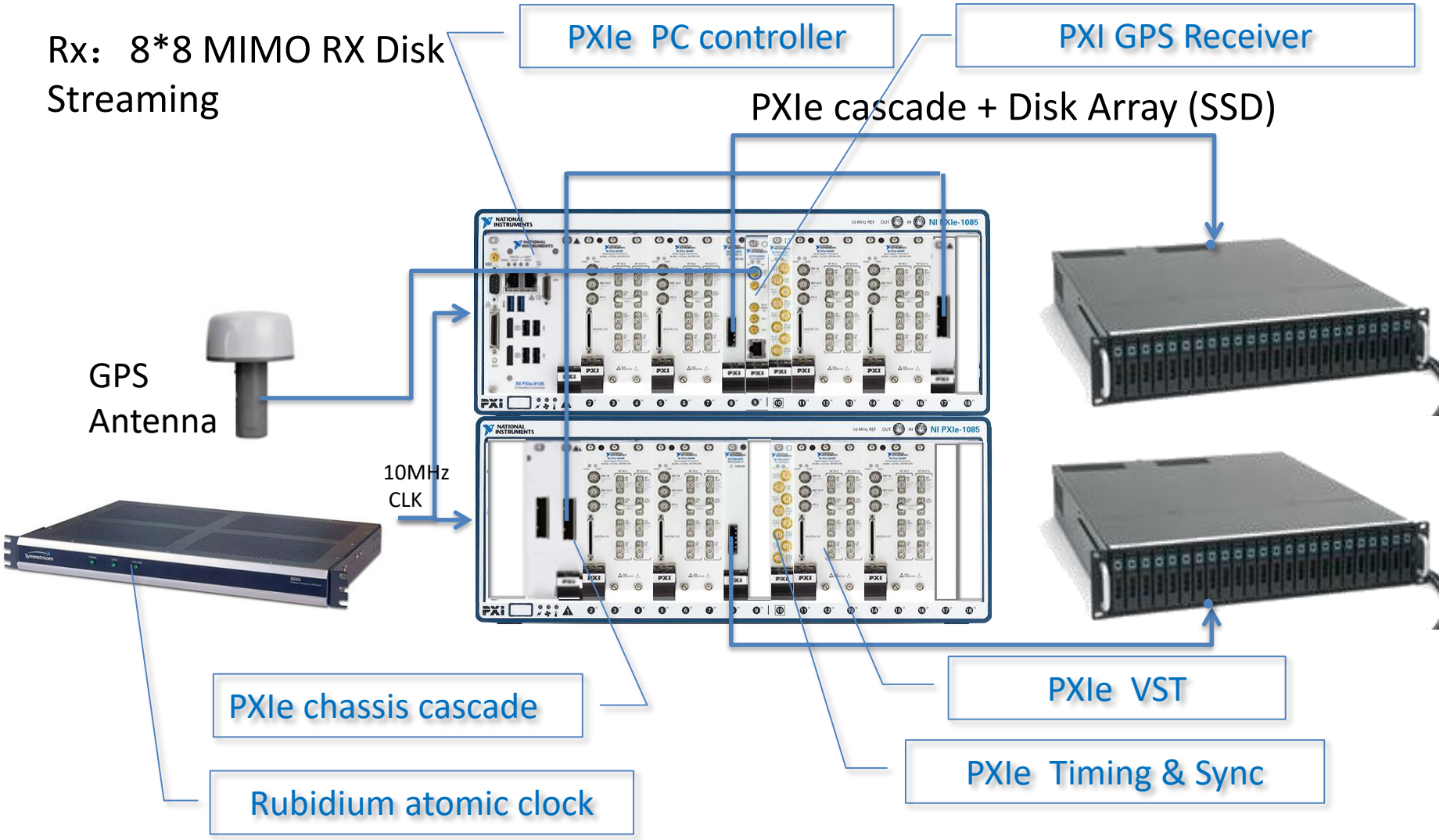
Transmitting Unit

Tx： 8*8 MIMO TX Part

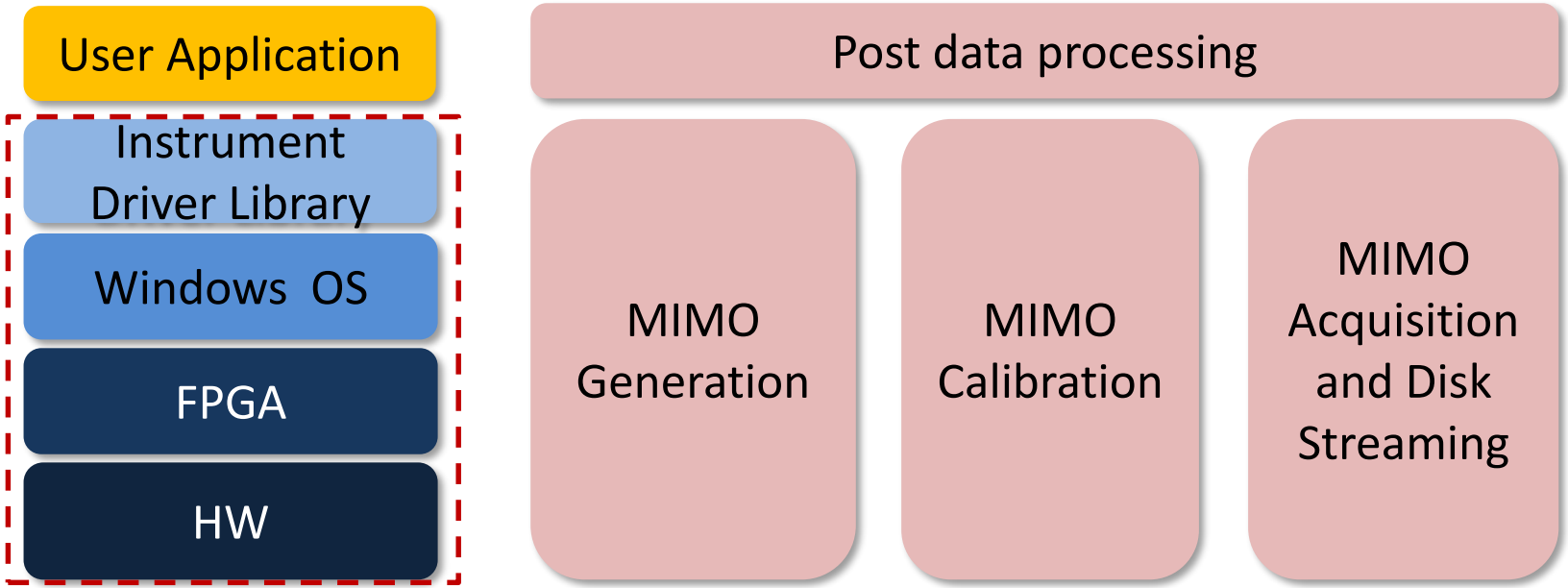


Receiving Unit

Rx： 8*8 MIMO RX Disk Streaming



Software solutions



Content

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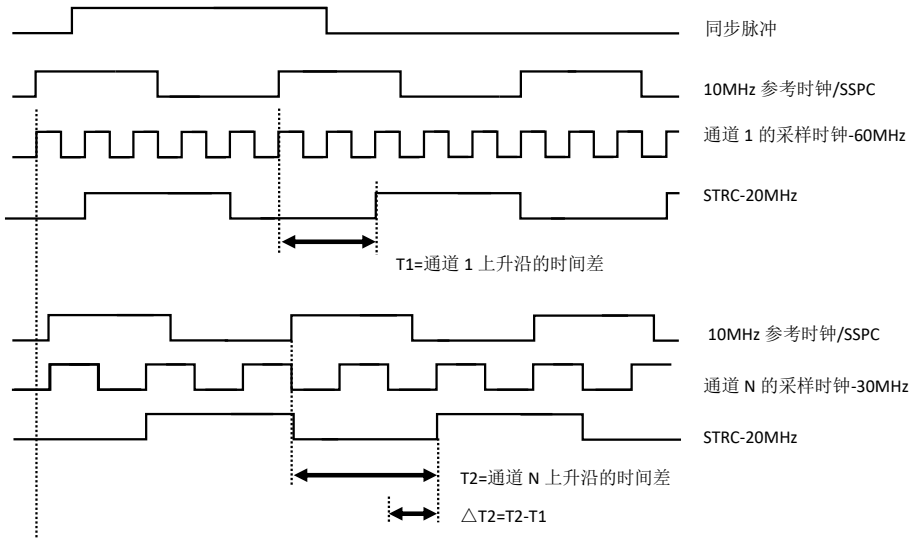
Channel synchronization

Challenge :

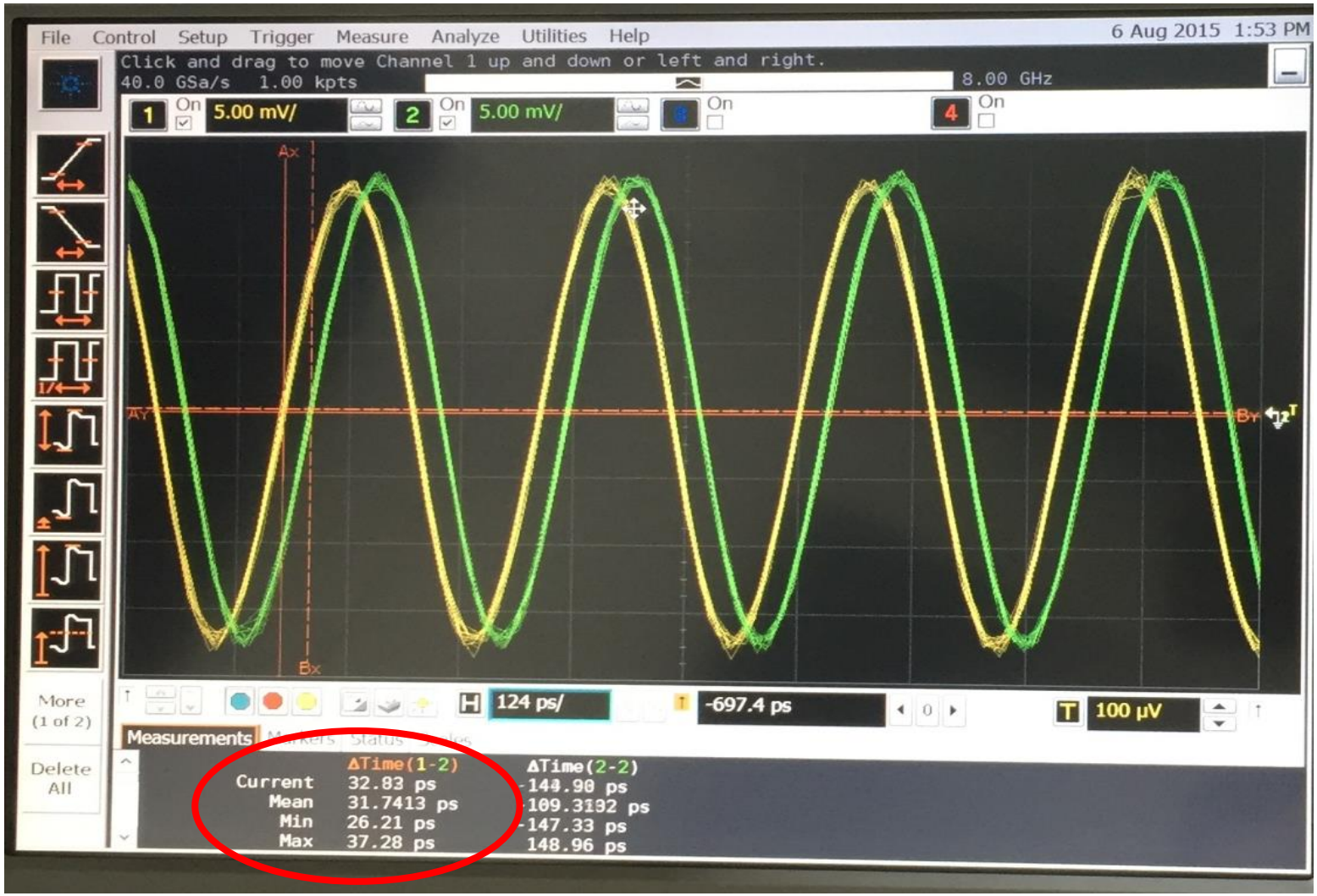
- Crosstalk , non-orthogonal error, path difference raise the phase difference
- Pico second level synchronization precision for accurate estimation
- Phase coherent Signal generation & Acquisition



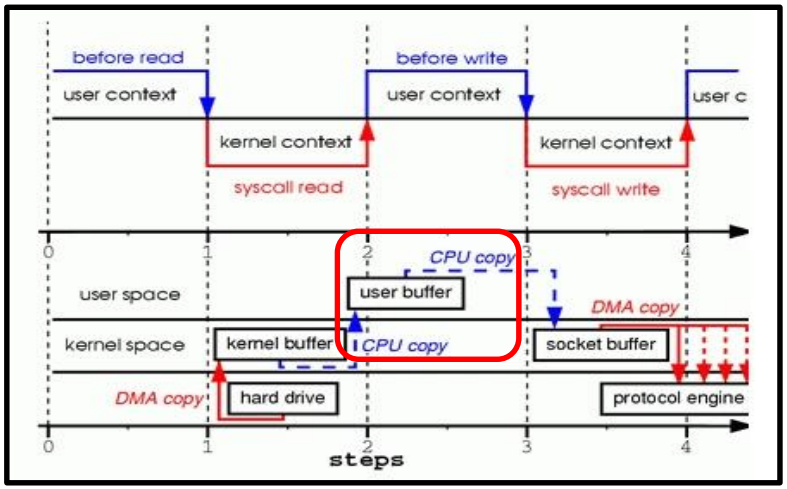
Implementation:

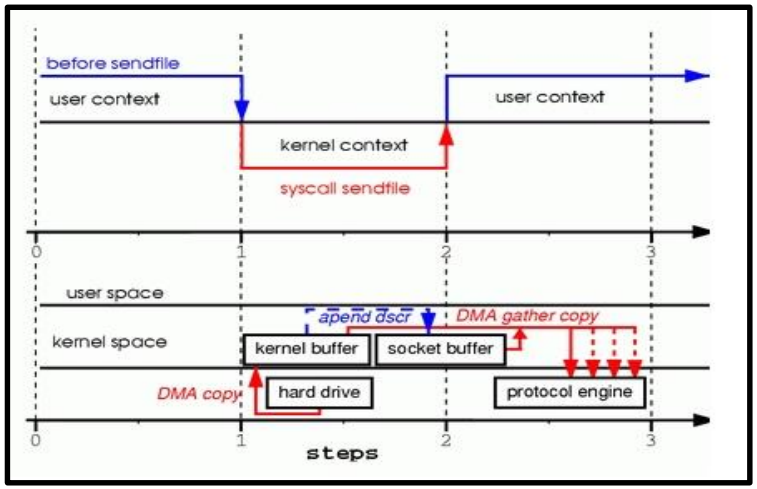
Timing jitter can be reduced to 30ps among 8 channels of MIMO parallel Channel sounder
The synchronization accuracy is less 1ns of Keysight M9391A （PXIeVSA） and M9381A （PXIe VSG）

Channel synchronization



Real-time data streaming

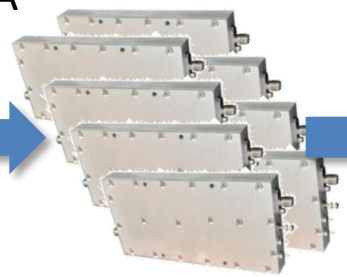


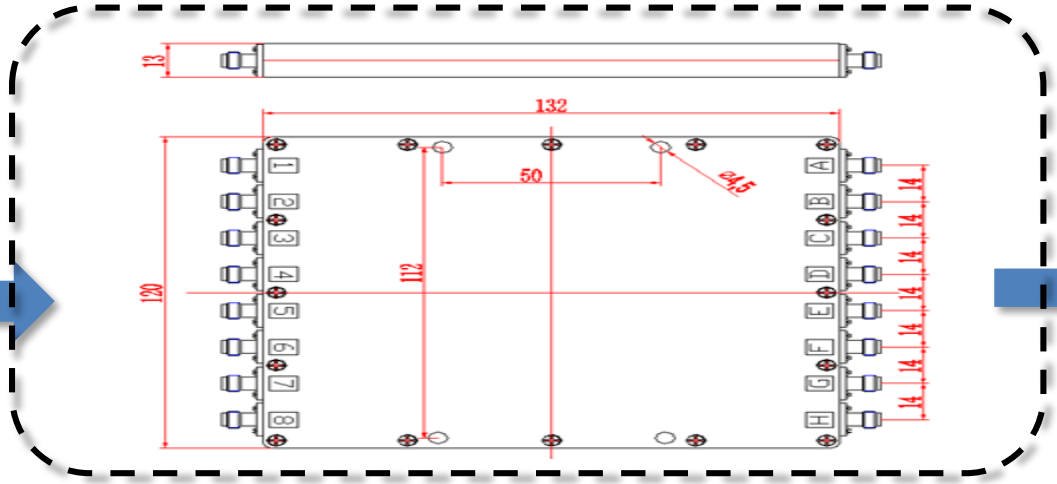


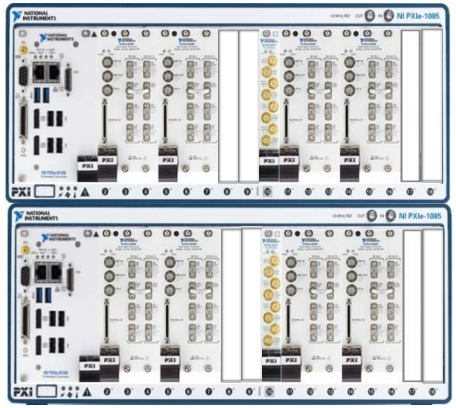
- P2P link between FPGA and SSD
- Zero-copy technology to reduce delay
- TDMS (Technical Document Management System) method for storage and data organization

Parallel channel calibration

10W PA







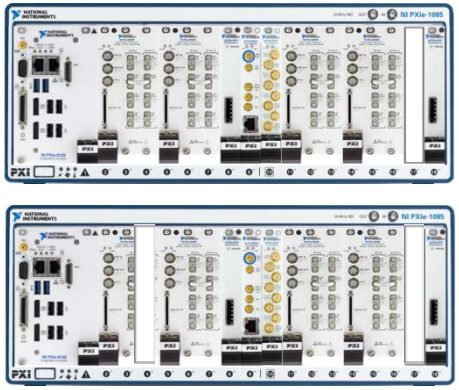
$$Y = RSTX$$

$$\tilde{Y} = RHTX + \tilde{N}$$

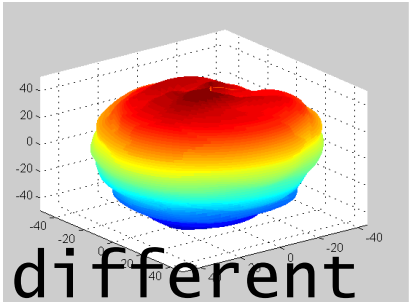
- Using VNA to get S (cali component)
- Using calibration data to get R (receiver) and T (transmitter)
- Using R and T to reconstruction signal

$$\underset{chanPara}{MAX}\,(P(\tilde{Y} \mid RH(chanPara)TX))$$

- Using ML to estimation channel parameter



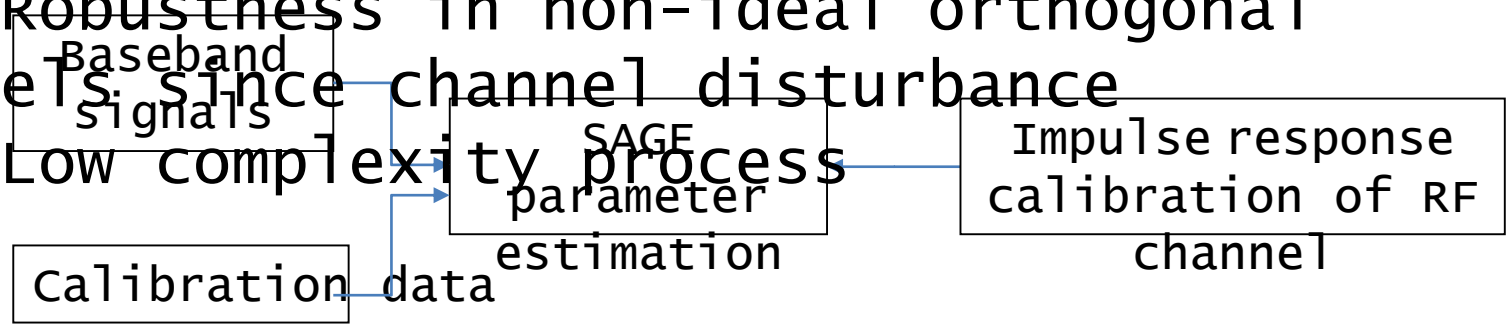
Post data processing



HRPE : PS-SAGE

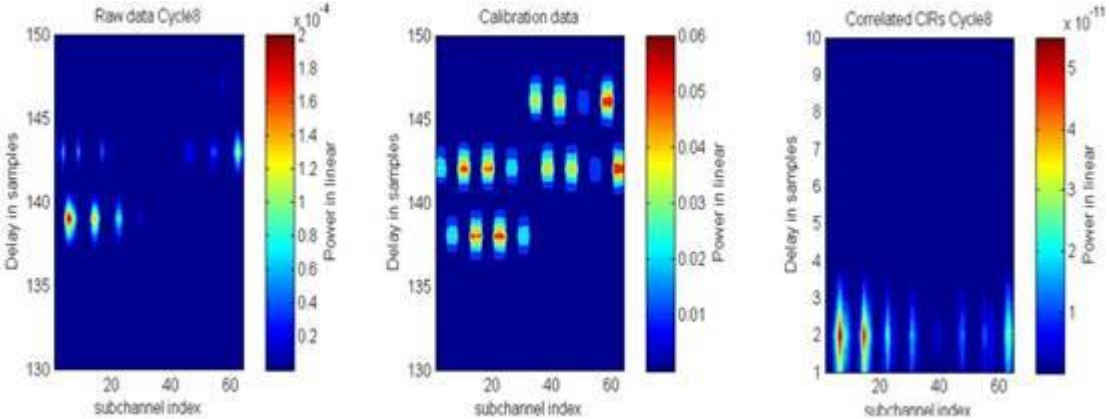
Parallel Sounder-SAGE(PS-SAGE)

- Considering coherence among the different channel
- Antenna pattern measurement using N paths transmitter and one path receiver
- Robustness in non-ideal orthogonal channels since channel disturbance
- Low complexity process



HRPE : High Resolution Parameter Esti

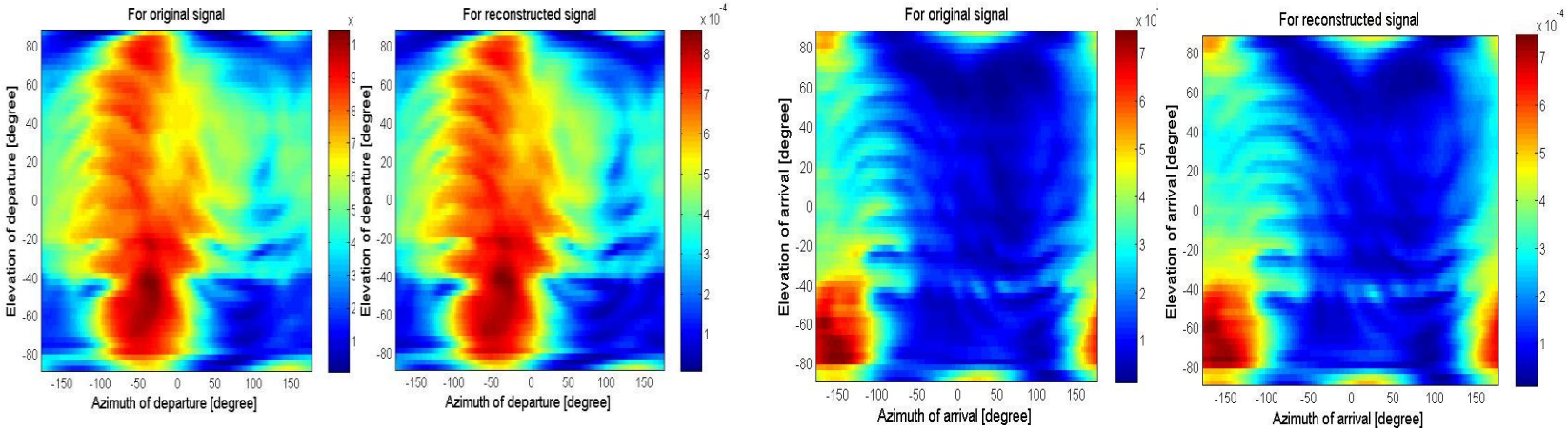
Parameters estimation



Using calibration data to correct different delay among multichannel

Parameter estimation is accurate

Reconstruction signal spectrum is highly similar to original signal spectrum



Key parameters

Parameter	PropSound	SHIFT
Center frequency / bandwidth	<6GHz	<6GHz
RF Channel /Tx（Rx）	1	8
Channel sounder method	TDM MIMO	Parallel
RF bandwidth	120Mhz	200Mhz
Transmitted power per antenna	27dBm~40dBm	15dBm~40dBm
dynamic range	40dB	30dB
multipath time resolution	8.33ns	5ns
maximum Doppler shift	30～60Hz	2kHz
maximum detectable speed of an object	<30kmh	>350kmh
Maximum impulse response	20.48us	20.48us
Data stored	CIR	Raw Data/CIR
Parameter method	SAGE	Parallel SAGE
Implement platform	customized	SDR

Advantages

- Advanced 8x8 parallel channel sounder
- Suitable for dynamic MIMO channel with high velocity
- Dynamic range comparable to TDM sounder
- Flexible and adaptive with SDR platform
- Interference cancellation by PS-SAGE
- Transferable to MIMO channel emulator

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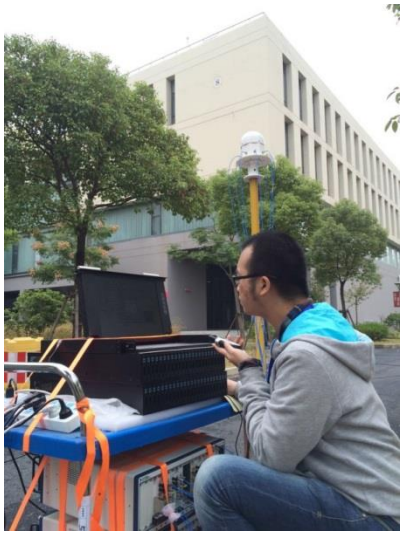
Measurement campaign







New function and capability

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Channel measurement Databank

1. Verification and Comparison

With ray tracing software

With channel emulator

2. Extend to 64*64

Parallel & Serial

3. mmWave Channel measurement

2GHz bandwidth

60-110GHz

Thank you！

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