SKA Shanghai 2019

Tianlai update

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NAOC

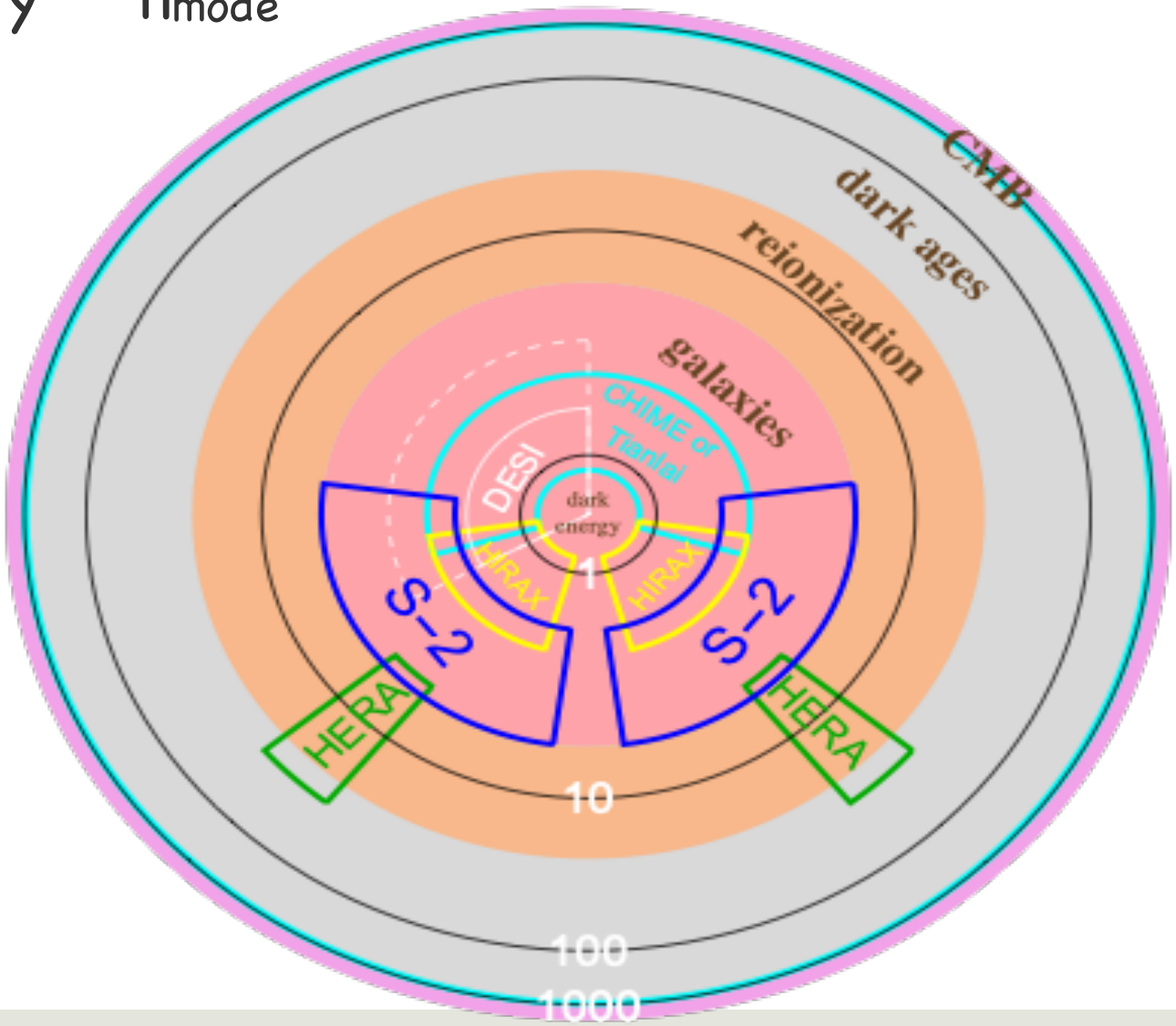
On behalf of Tianlai International Cooperation Group

2019.11.26 shanghai

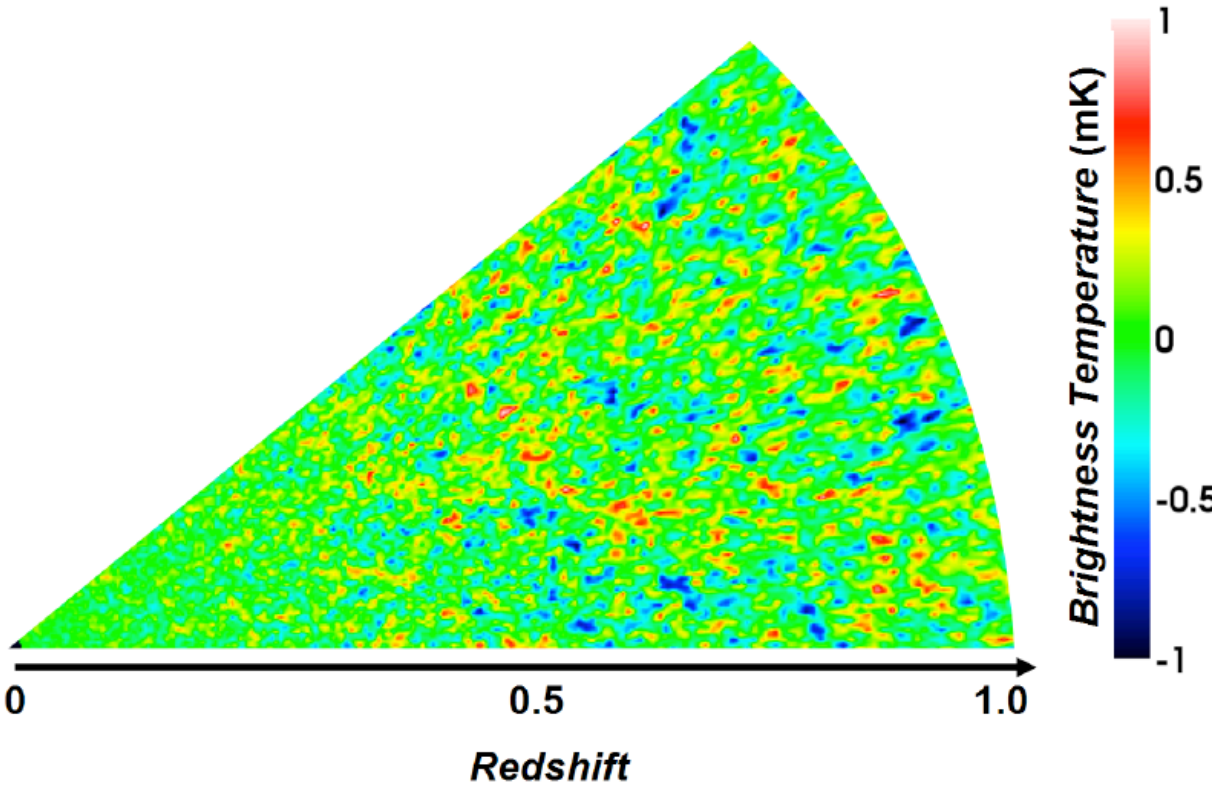
Goals of Tianlai project---Dark Energy

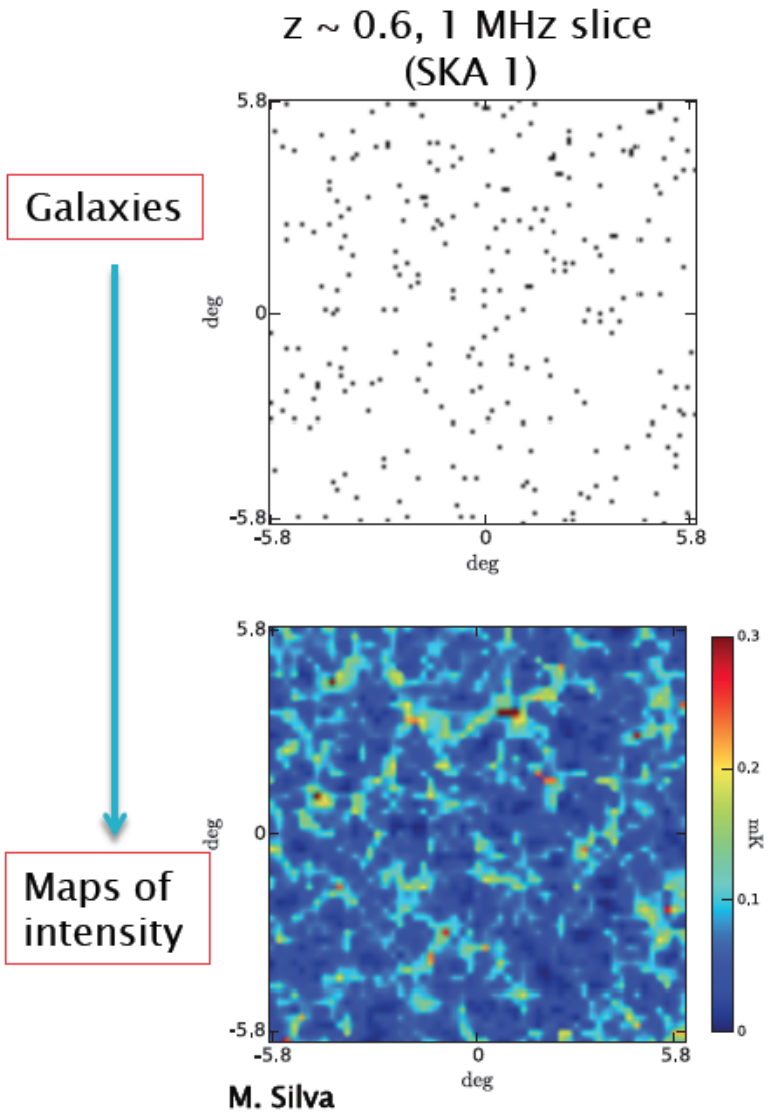
parameter accuracy ~ $n_{mode}^{-1/2}$

n_{mode} ~ volume



Intensity Mapping





The Tianlai (Heavenly Sound) Project

NAOC(Xuelei Chen, Fengquan Wu, Yougang Wang, Shijie Sun, Shifu Li), Xinjiang Observatory, CETC-54, Institute of Automation, Hangzhou Dianzi U.

US: CMU(Peterson), U. Wisconsin (Timbie), Fermilab(Stebbins)

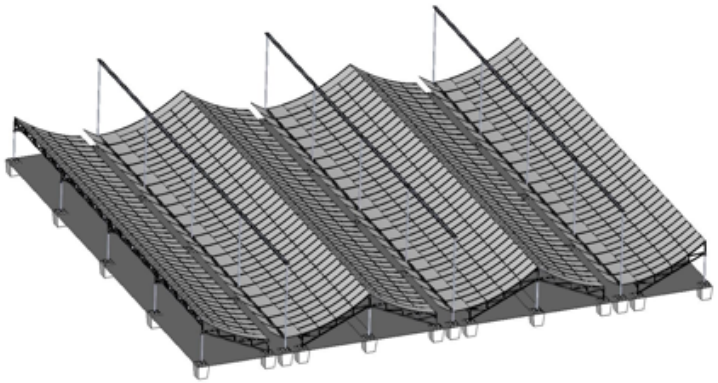
LAL/IN2P3 (R. Ansari, J.E Campagne, M. Moniez), Obs. Paris (J.-M. Martin, P. Colom) , IRFU-CEA(C. Magneville, C. Yeche), CITA(Pen), KASI (Song), ASIAA(Chang)

Monthly Telesconf and annual Collaboration Meeting since 2010

The concept of "tianlai"-- the heavenly sound was coined by ancient Chinese philosopher Zhuang-Zi (Chuang-Tzu, 369BC-286BC)

Tianlai pathfinder experiment

•A small pathfinder experiment to check the basic principles and designs, find out potential problems

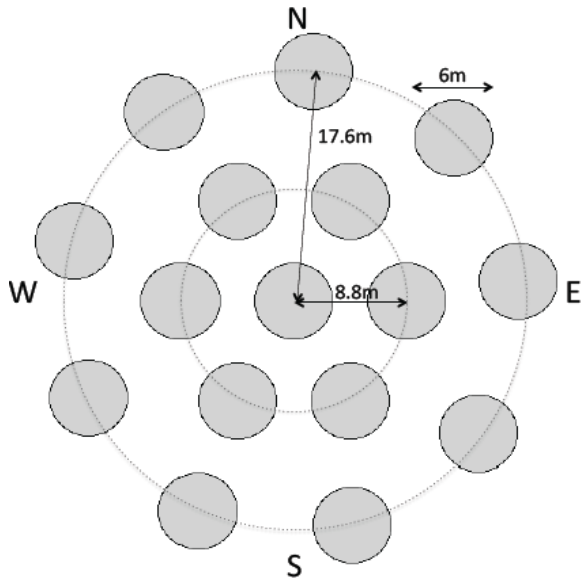


• 3x15mx40m cylinders, 96 dual polarization receiver units

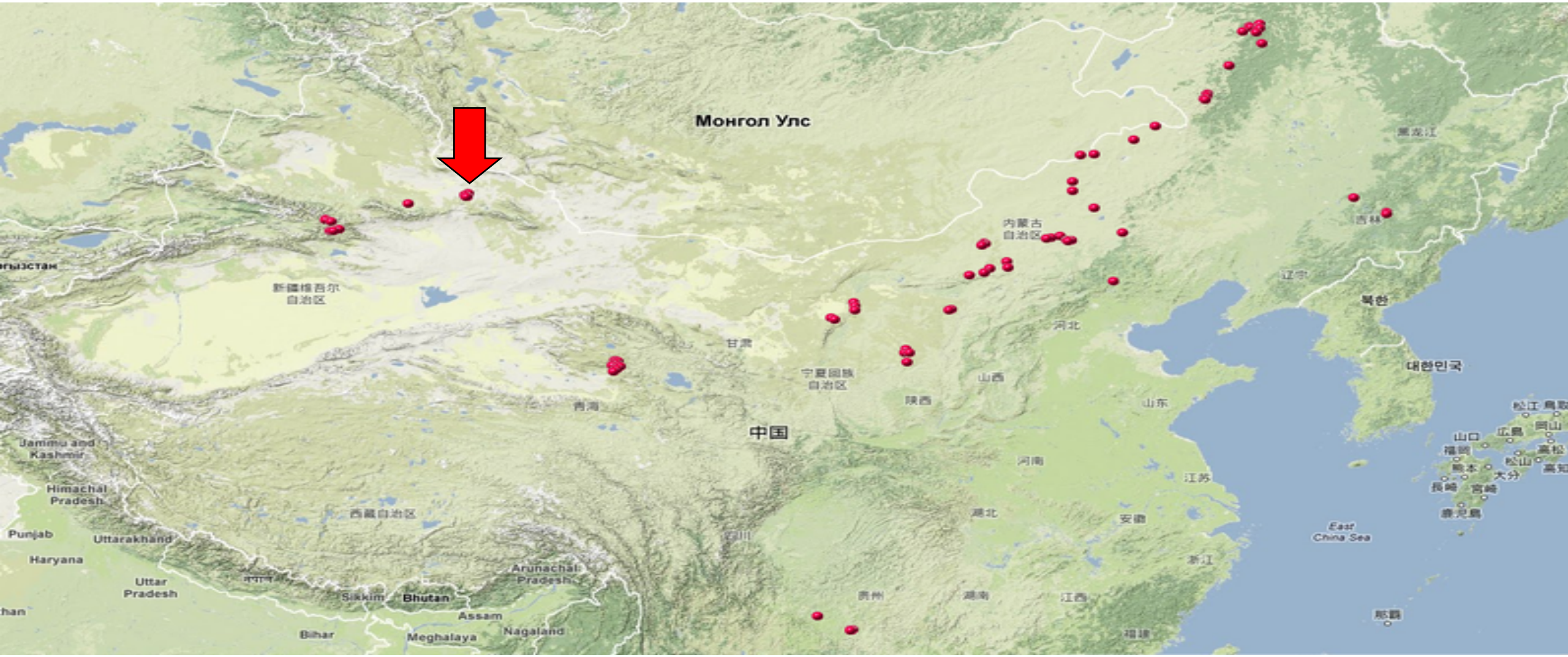
• 16x 6m dishes

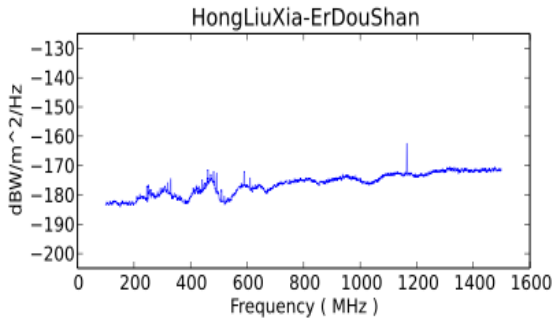
• Frequency: 400-1400MHz (Redshift z=0-2.5)

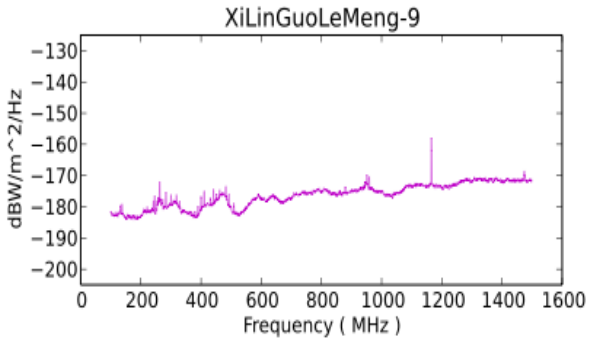
• If successful: expand up to 110mx110m, 1000~ 3000 units, cover full wavelength range

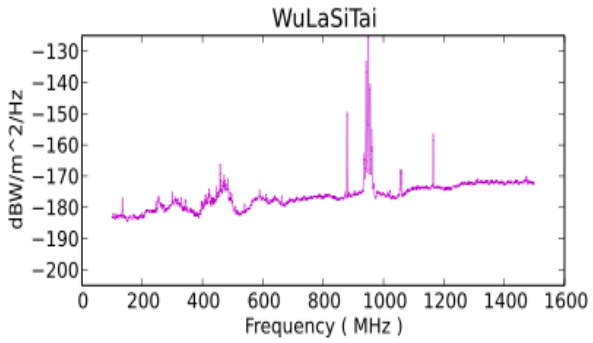


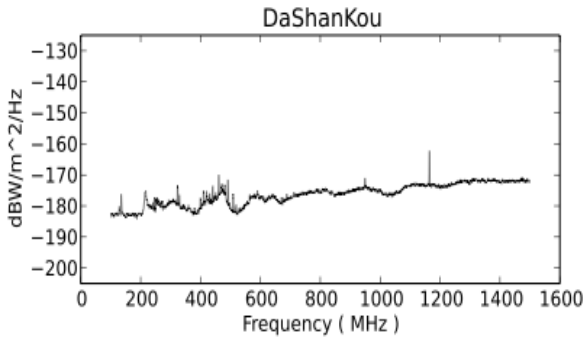
Site Selection

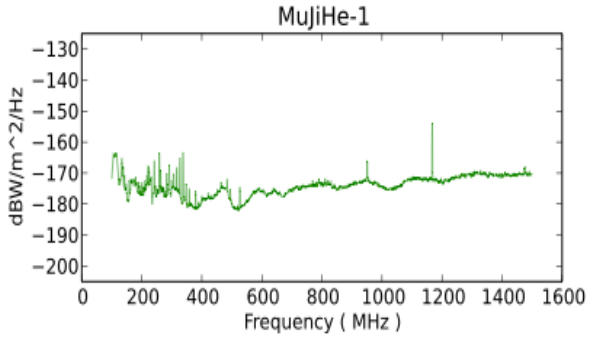


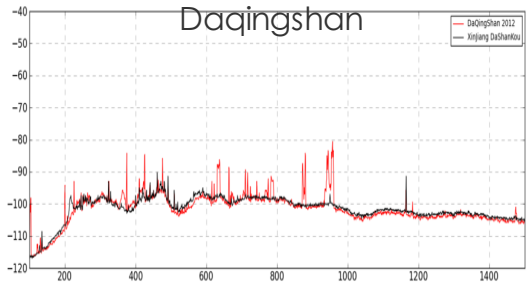

HongLiuXia-ErDouShan
dBW/m^2/Hz
Frequency (MHz)

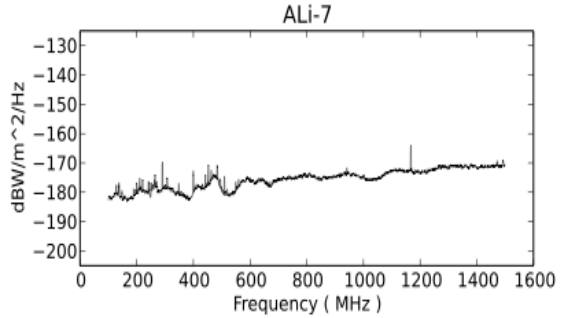

XiLinGuoLeMeng-9
dBW/m^2/Hz
Frequency (MHz)

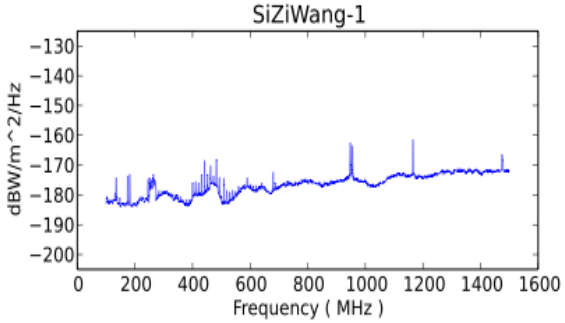

WuLaSiTai
dBW/m^2/Hz
Frequency (MHz)

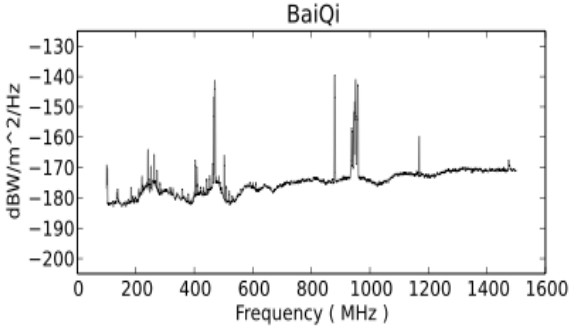

DaShanKou
dBW/m^2/Hz
Frequency (MHz)


MuJiHe-1
dBW/m^2/Hz
Frequency (MHz)

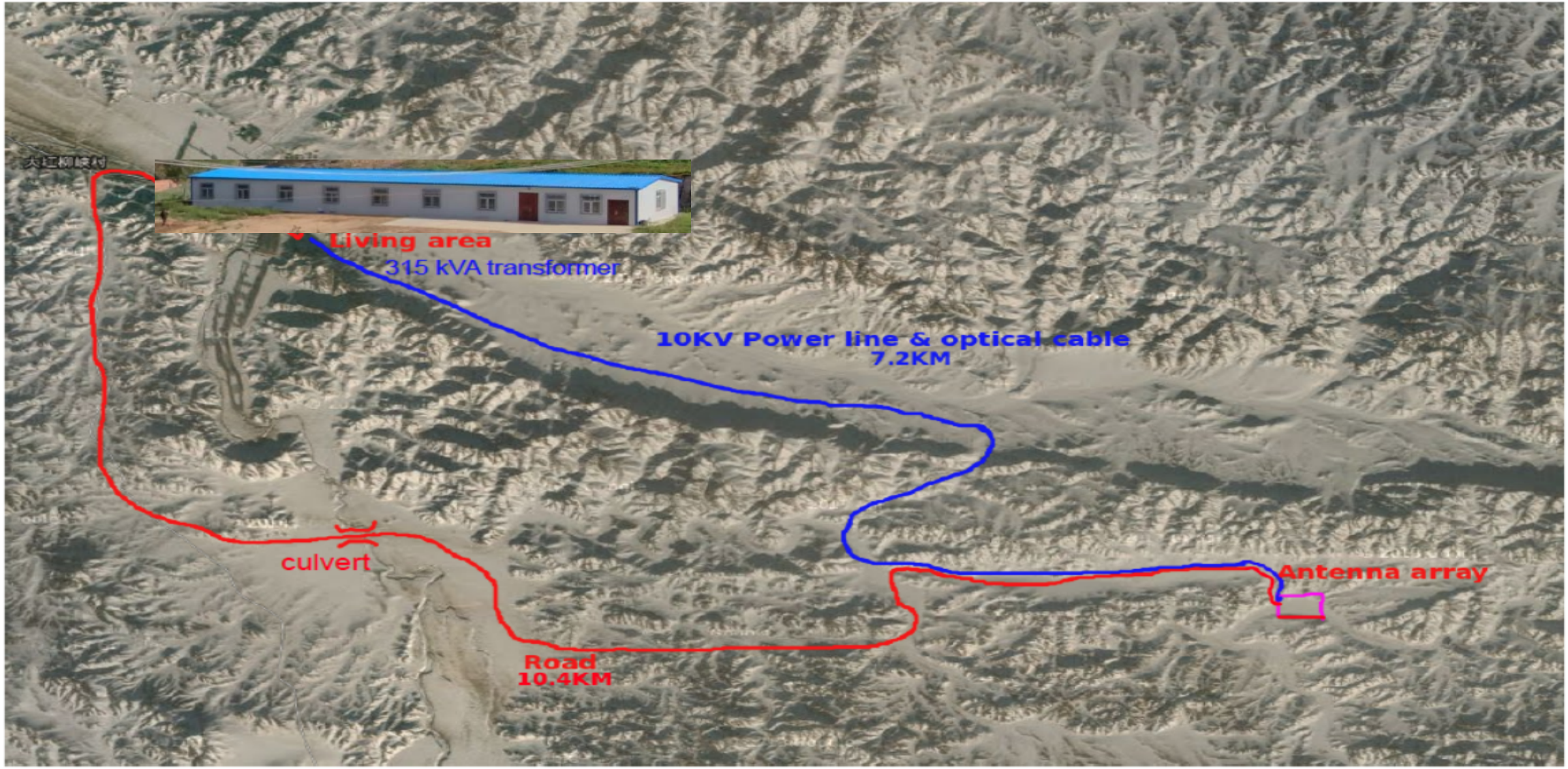

Daqingshan

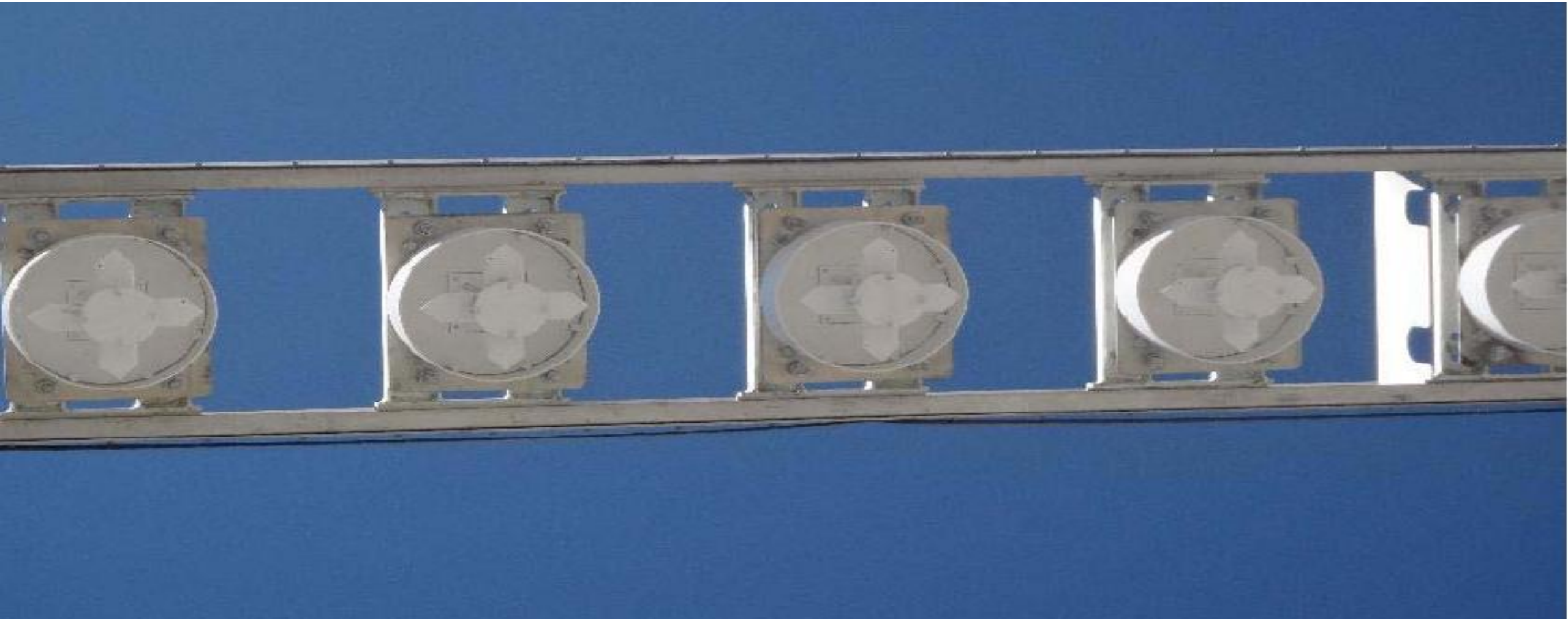

ALi-7
dBW/m^2/Hz
Frequency (MHz)


SiZiWang-1
dBW/m^2/Hz
Frequency (MHz)

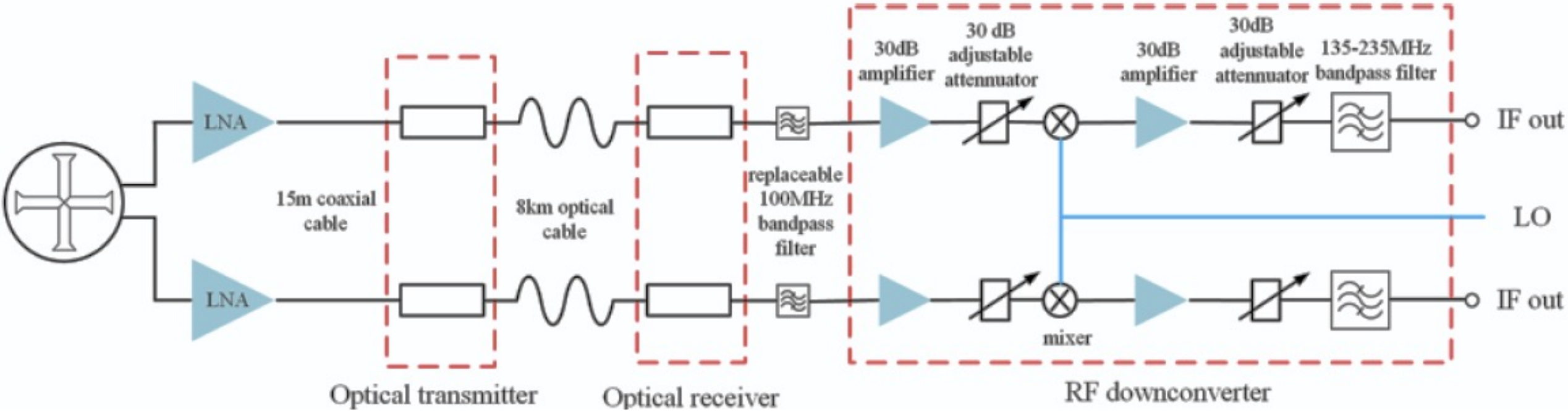

BaiQi
dBW/m^2/Hz
Frequency (MHz)

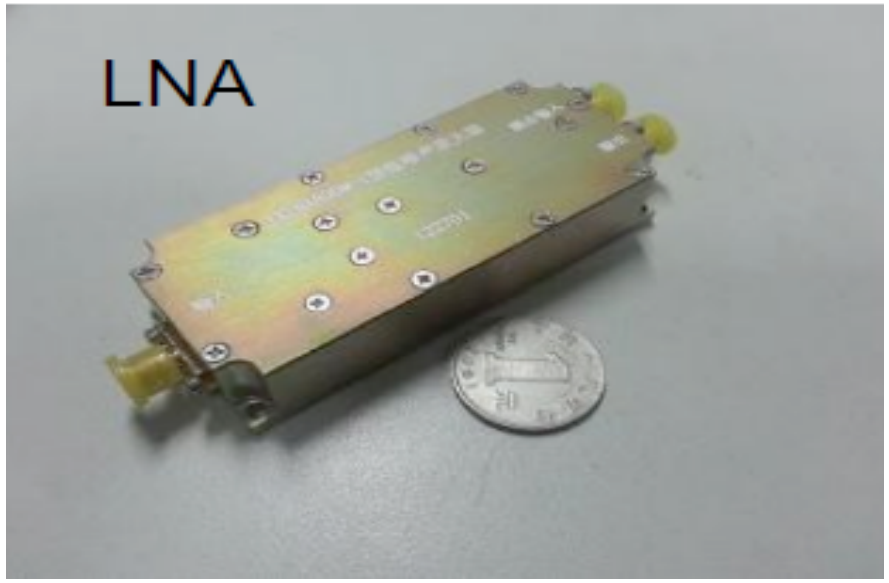
Map of Site


Living area
315 kVA transformer
10KV Power line & optical cable
7.2KM
culvert
Antenna array
Road
10.4KM

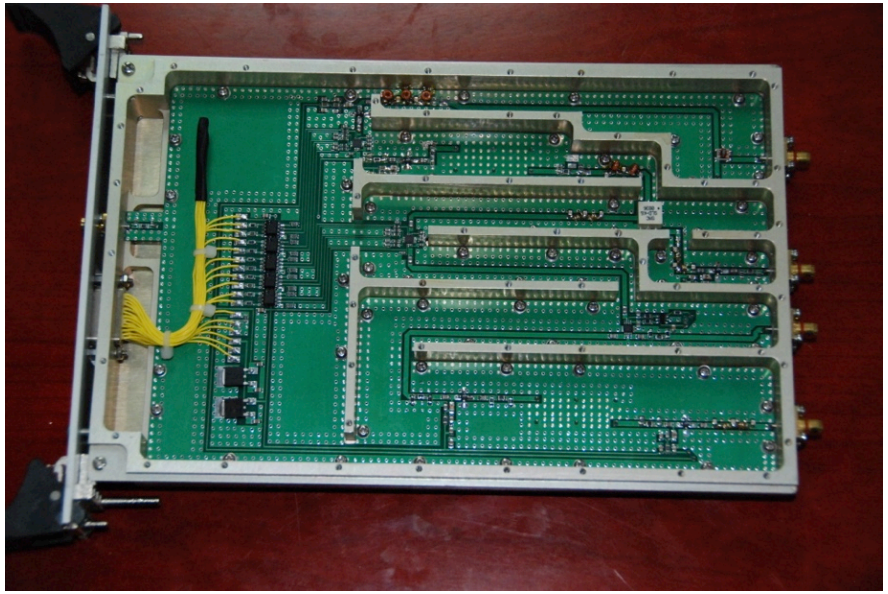


Electronic system

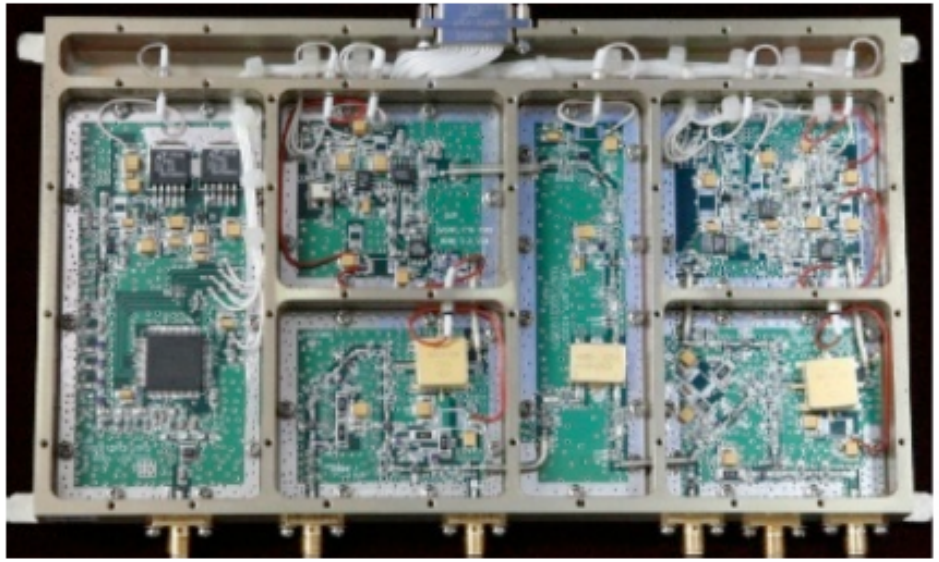




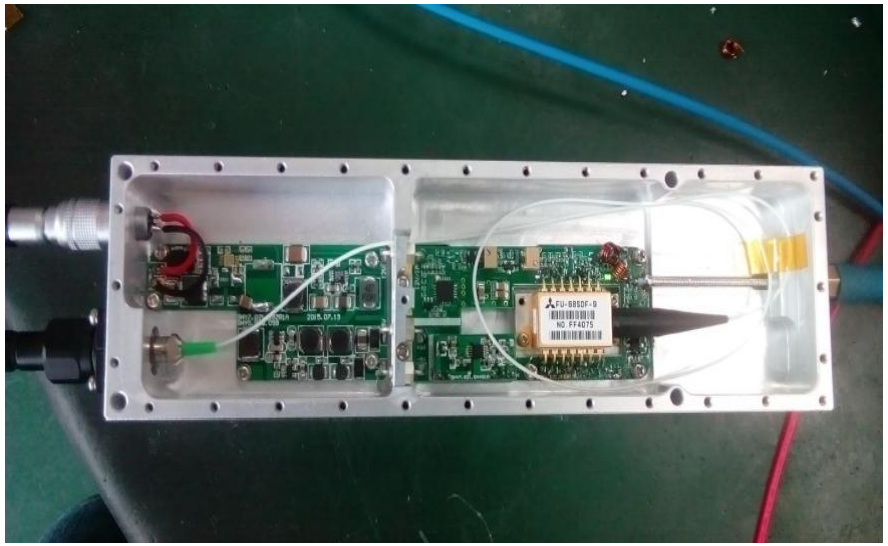
LNA



Mixer



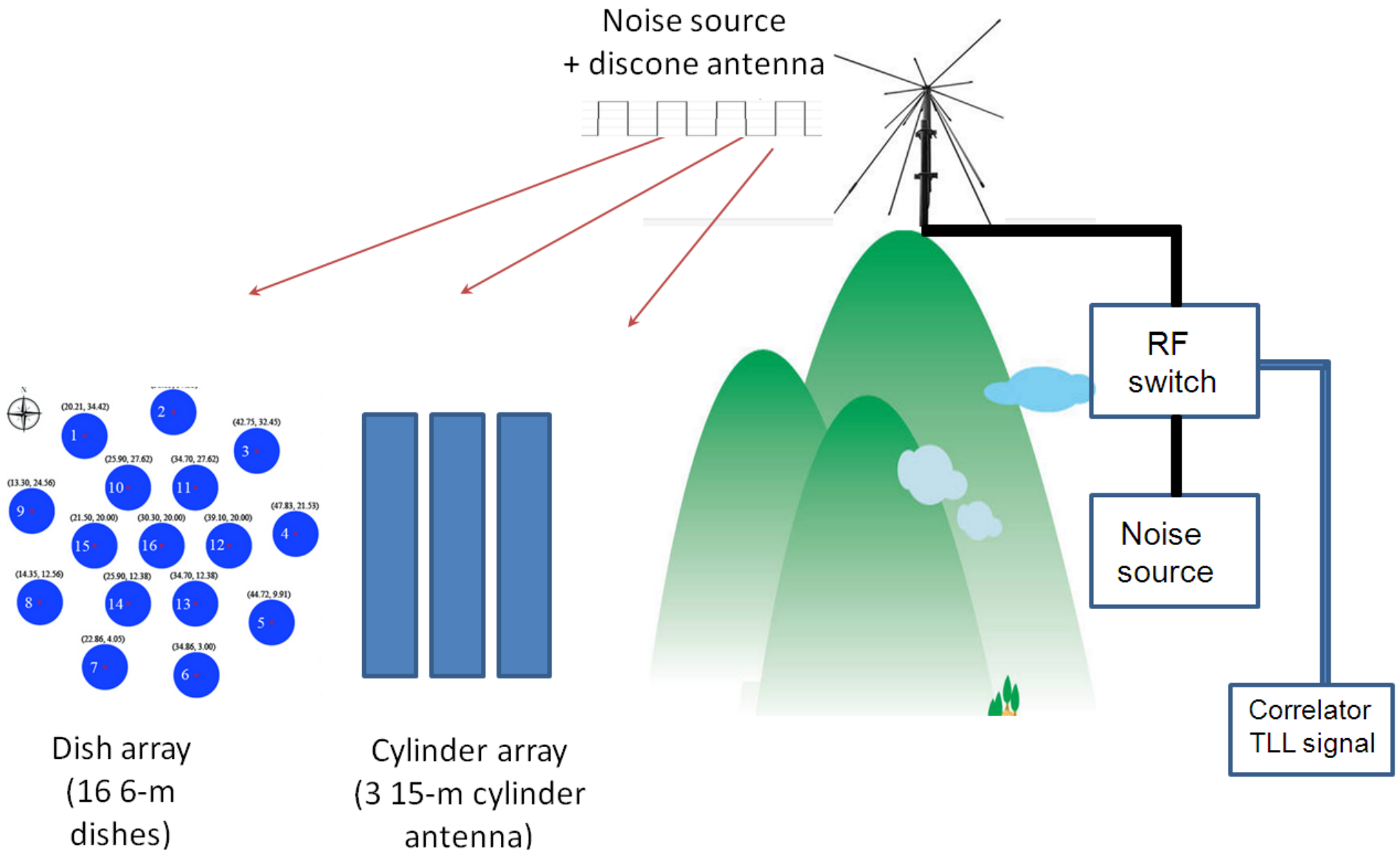
LO



Optical transmitter

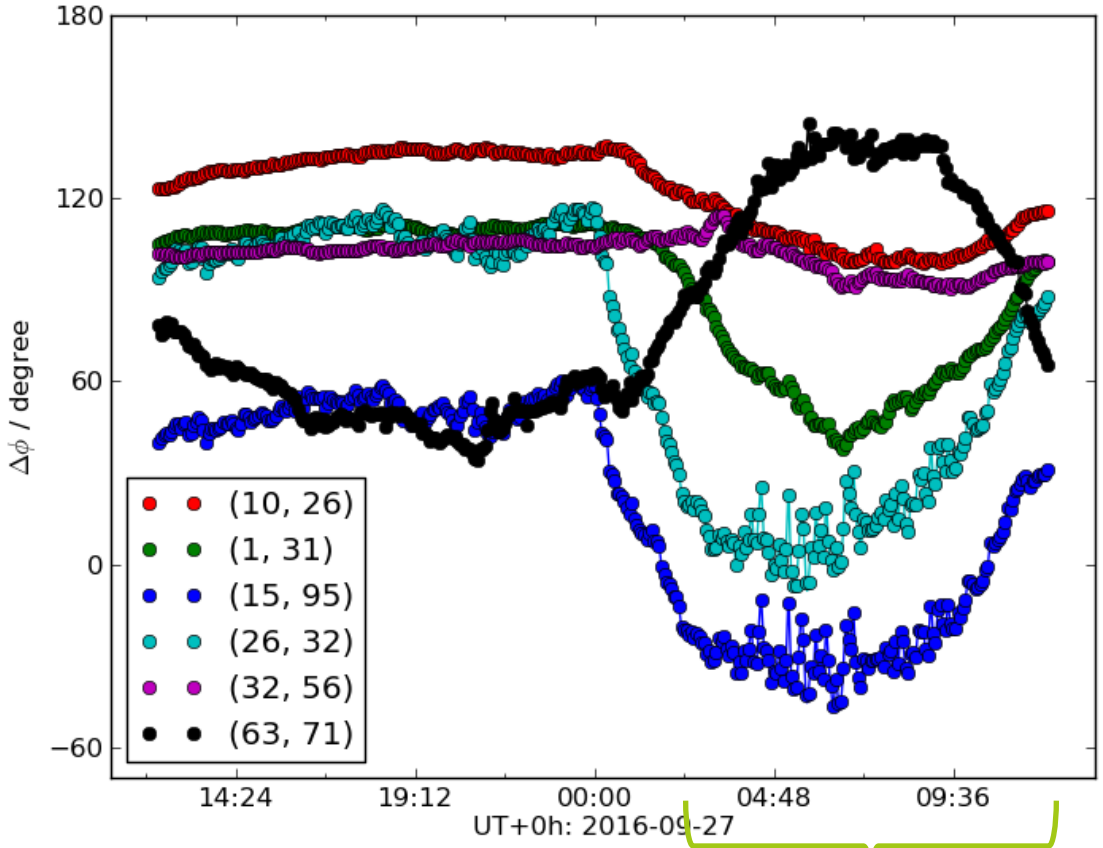
Receiver and Correlator

Calibration hardware: noise source



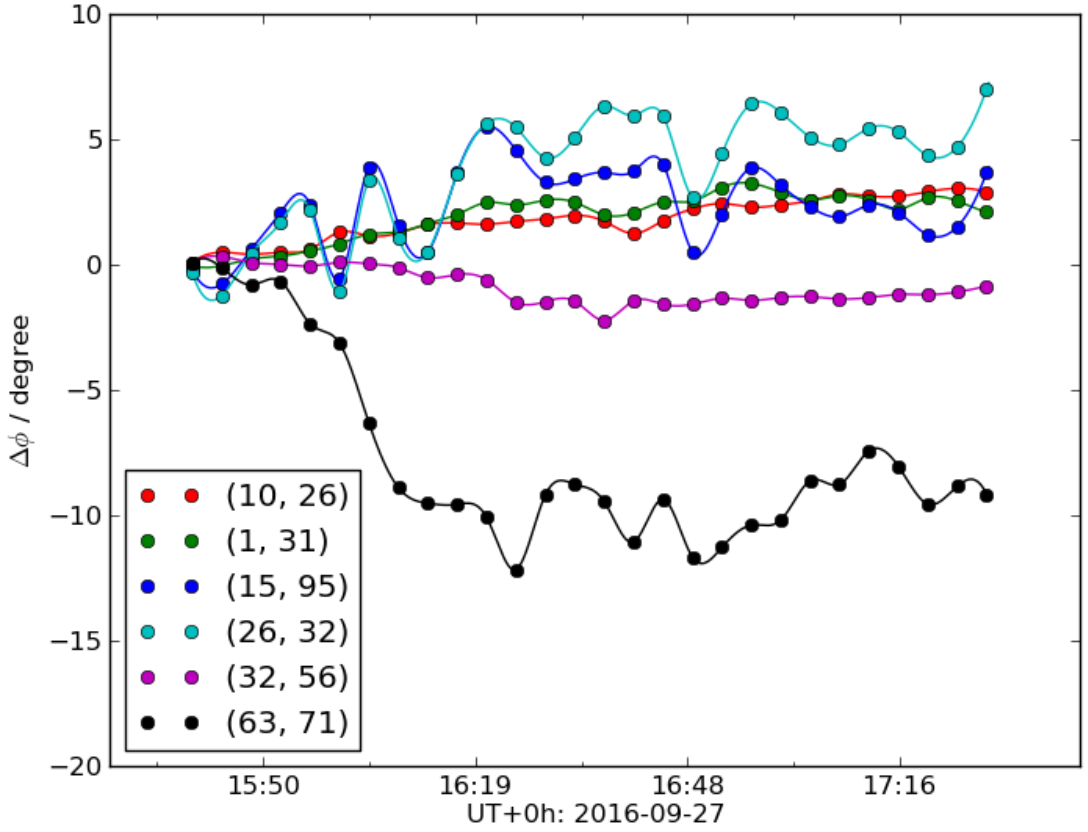
Noise source for relative calibration

Phase variation in one day



Day time

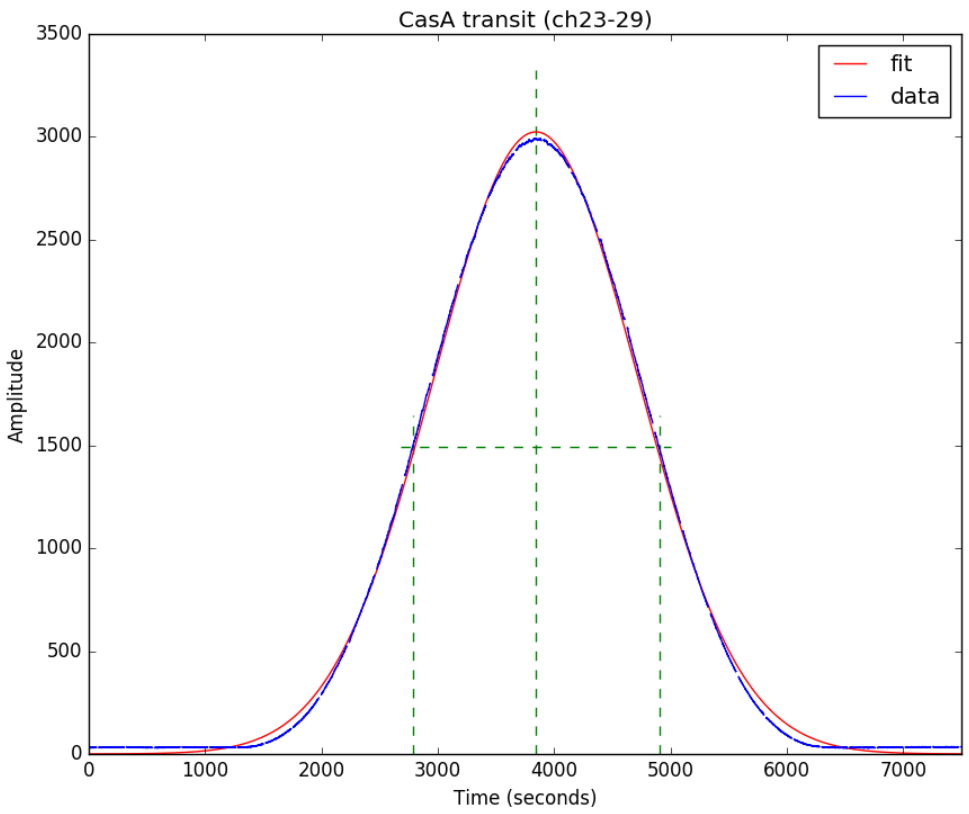
Phase variation in two hours

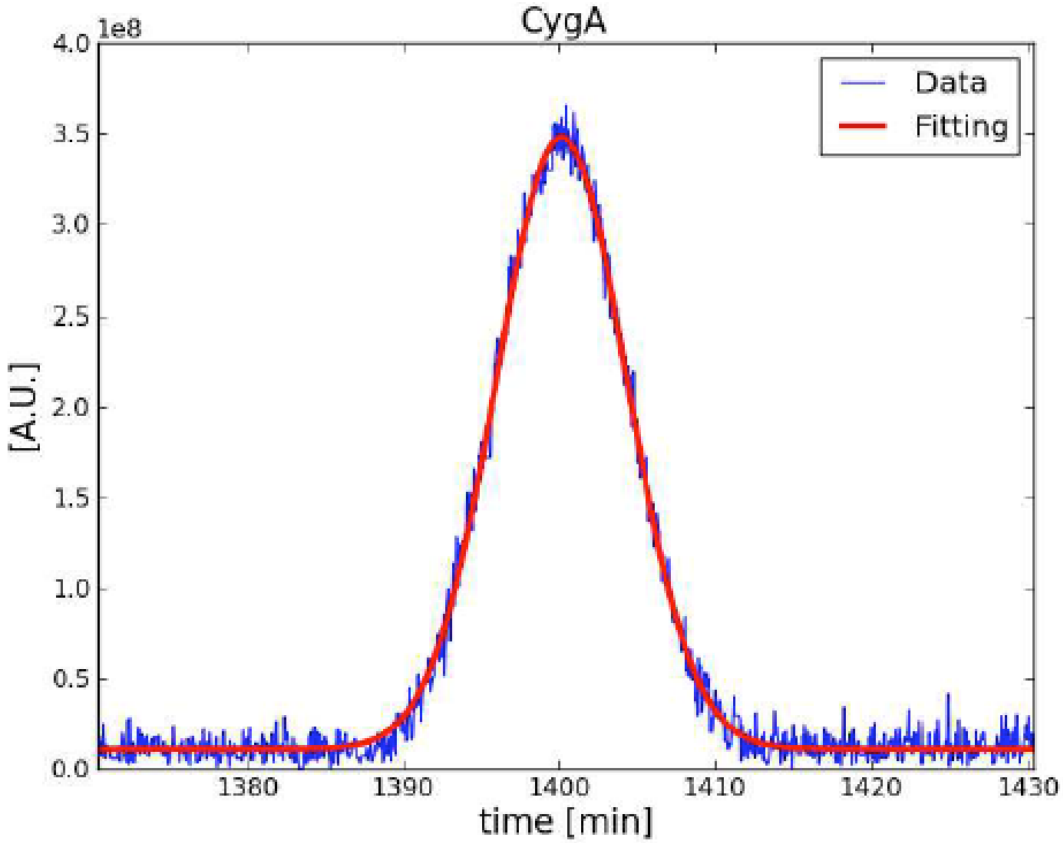


highly-repeatable visibilities

- one visibility
- staring at NCP for 10 nights

System testing: System temperature





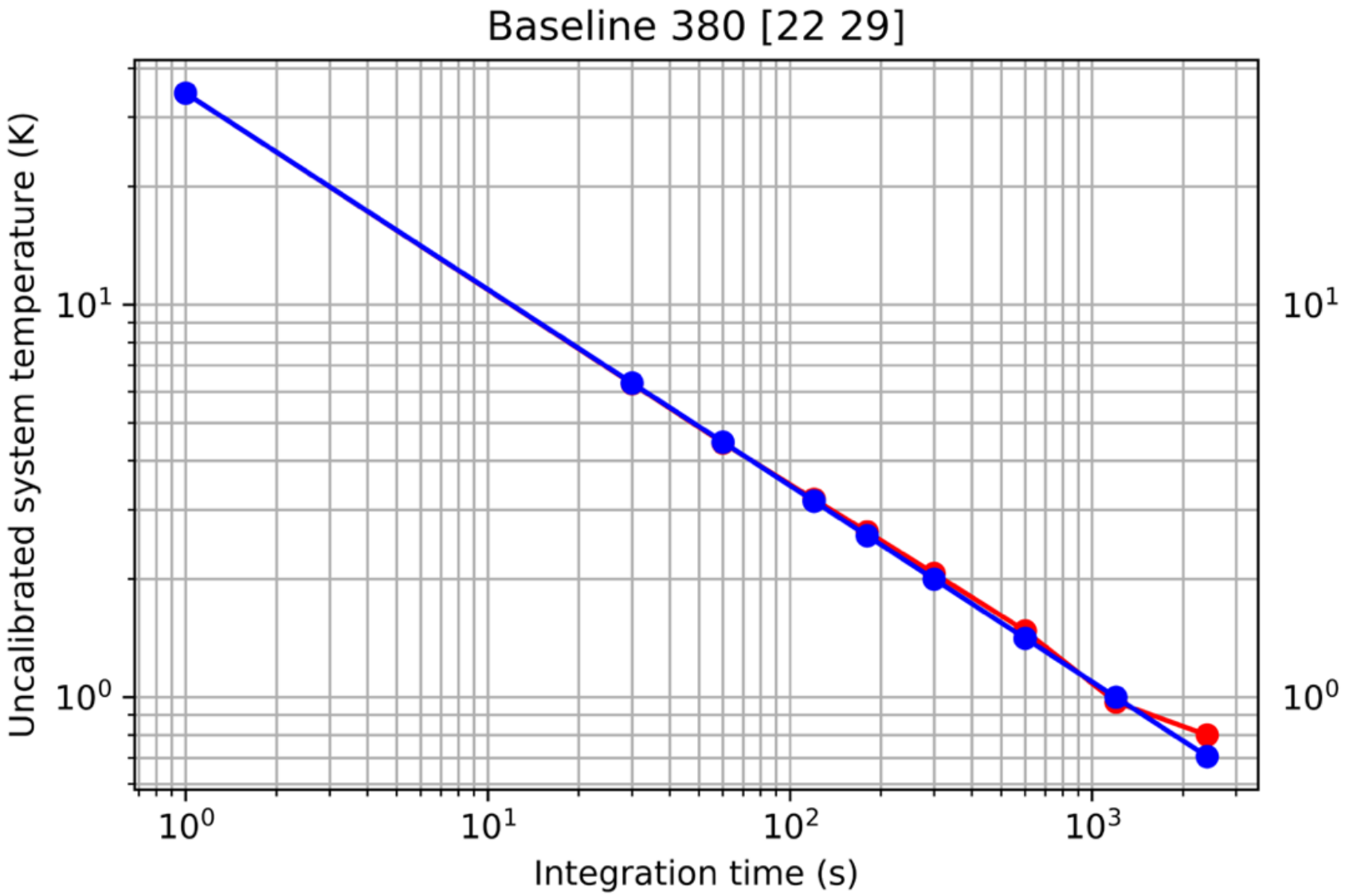
Dish

T_{sys}=87.2K

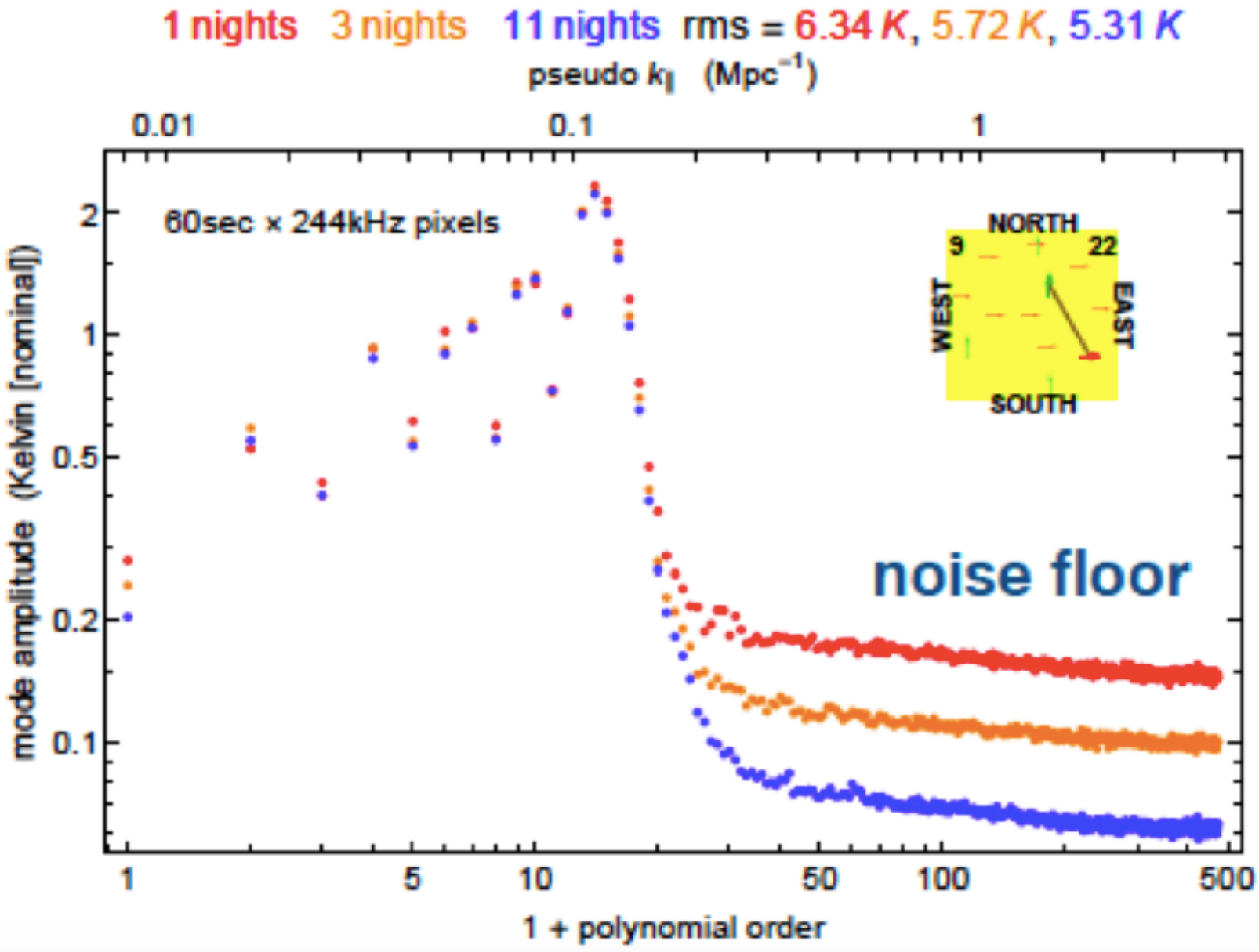
Cylinder

T_{sys}=79K

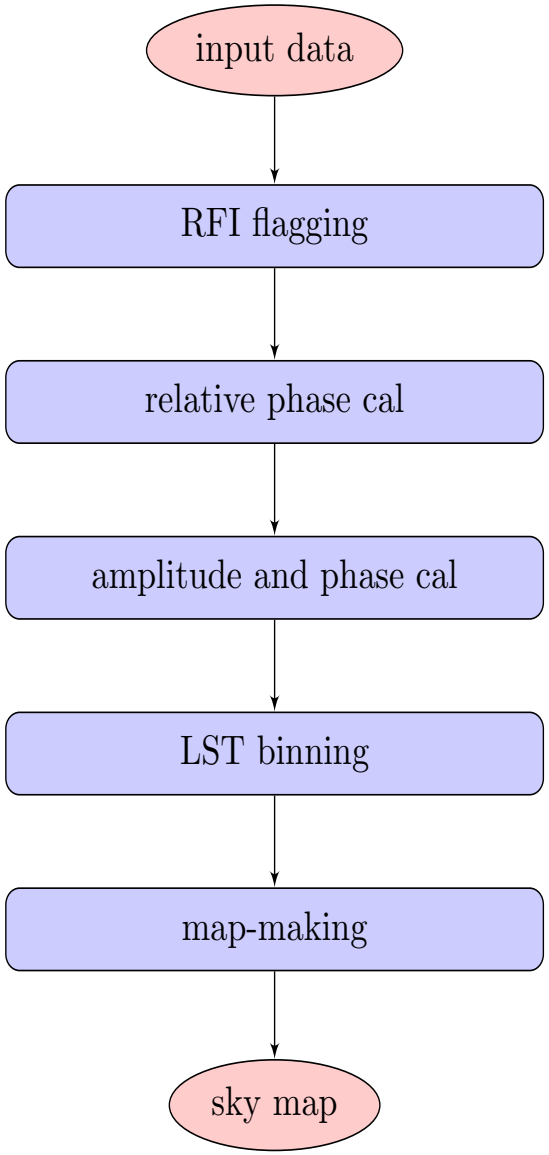
Noise integrates down



Tianlai Visibility: Foreground Subtraction



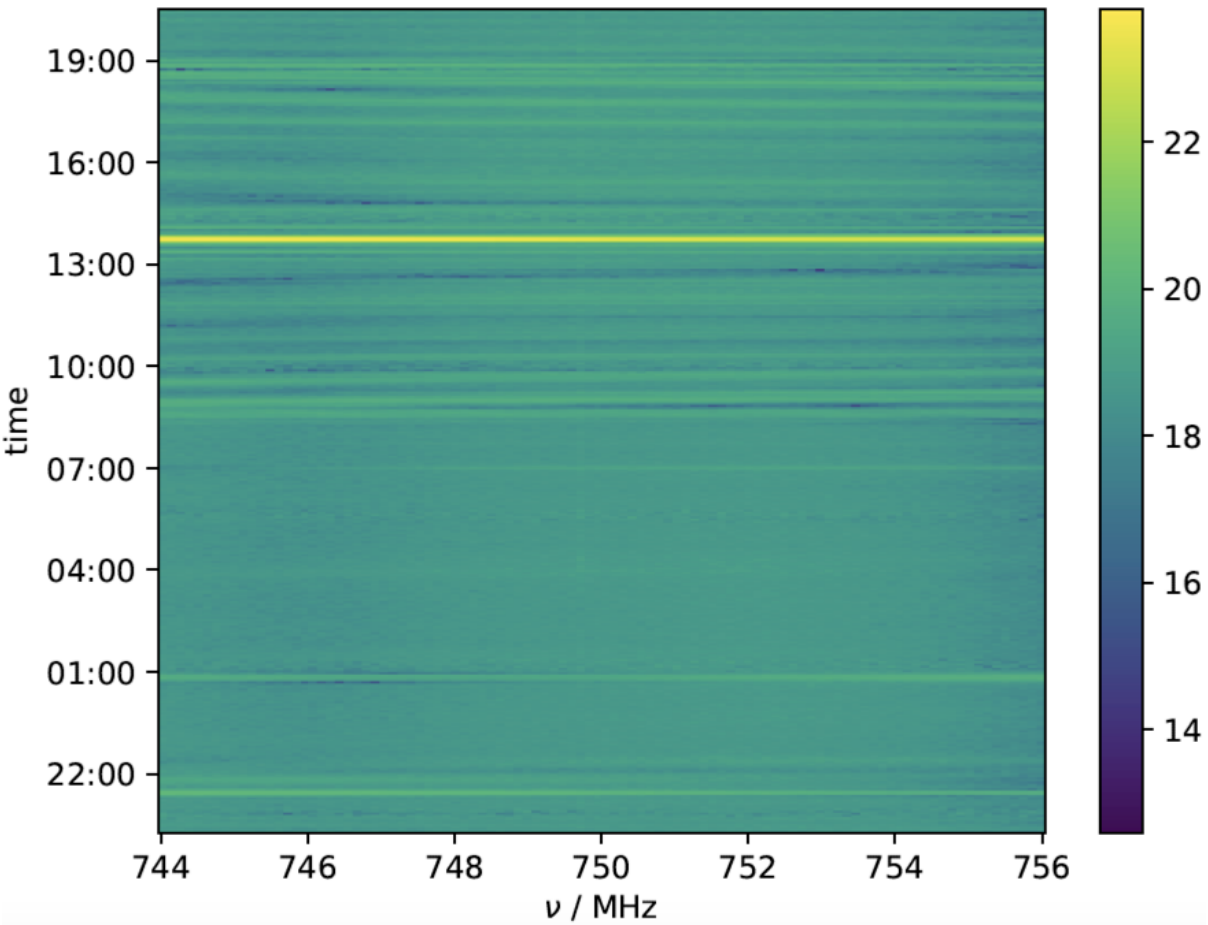
Data analysis Pipeline



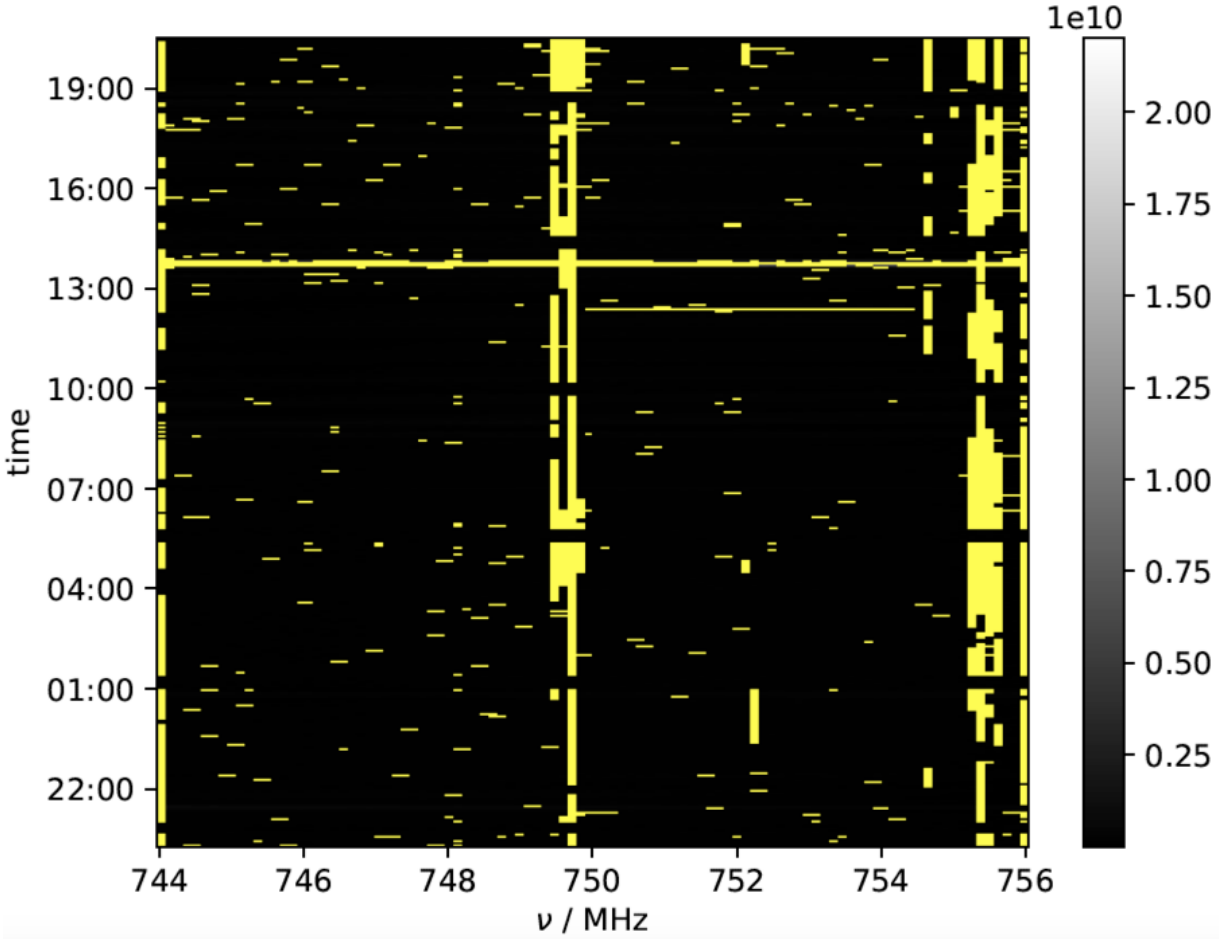
- Python
- Class
- MPI
- HDF5

RFI flagging

Raw data



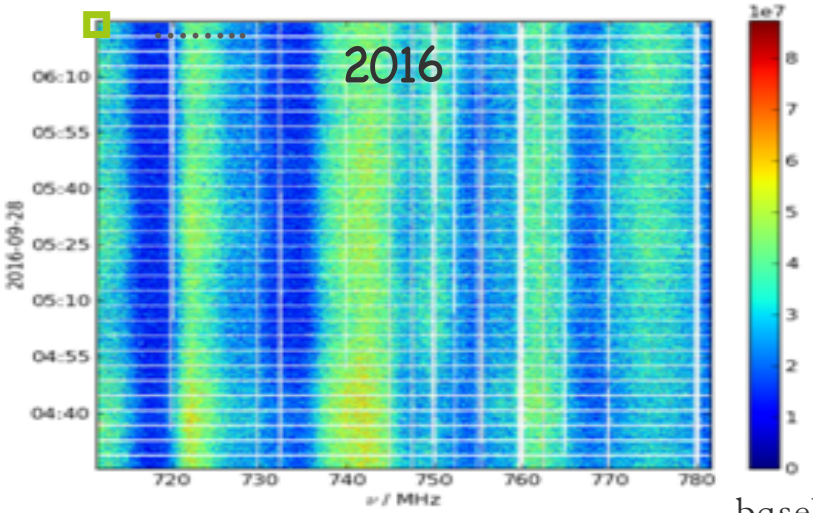
Flag data

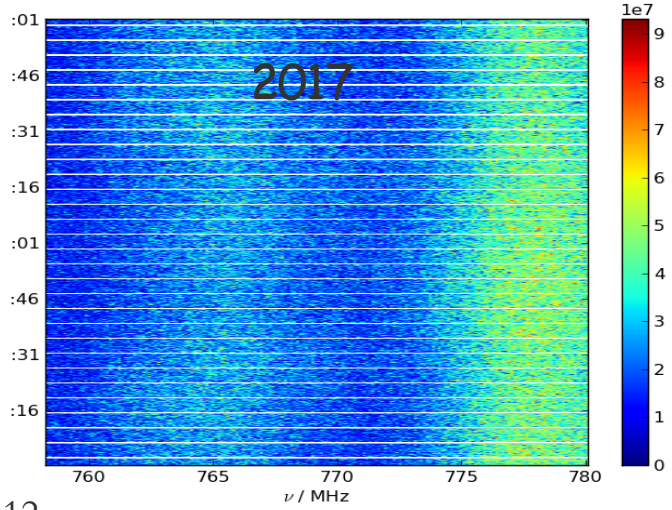


Sum-threshold method

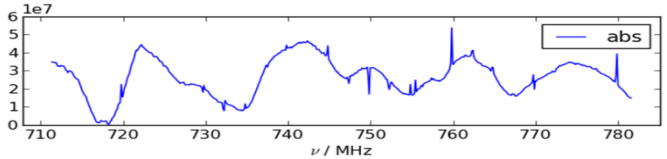
RFI on site---hardware improvement

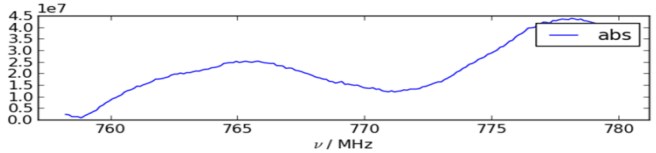
- Strongest RFI on site: digital control board and motor of dish antennas, serial server, network devices, switching power supply, DC fan…..
- Make a suit of optical switch to shut down all of the unnecessary devices when doing observation.
- DC fan replaced by AC fan, switching power supply replaced by linear power supply
- Faraday cage for high voltage transformer





baseline: 30-12





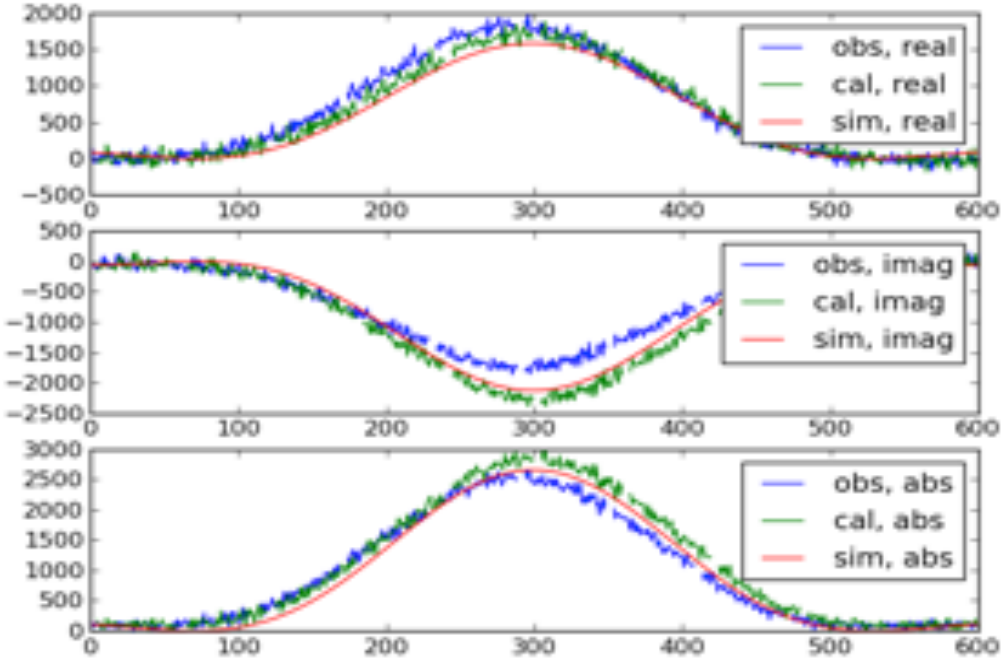
Bright source calibration(Absolute cal)

Method (1) Fringe fitting

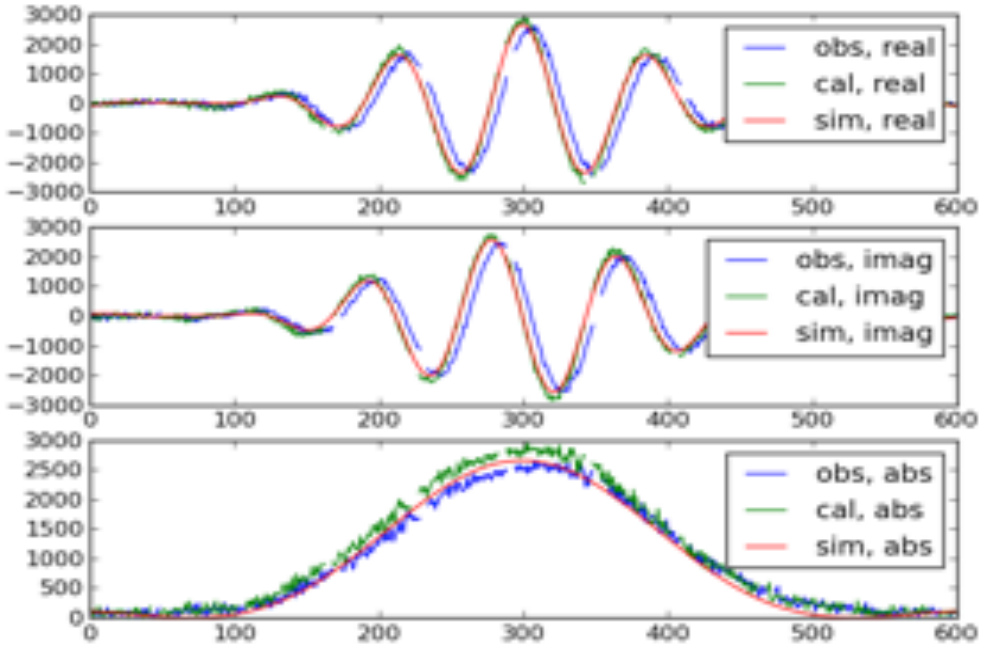
Real

Imaginary

Abs



NS baseline 12.4m



EW baseline 30m

@ Cas A transit

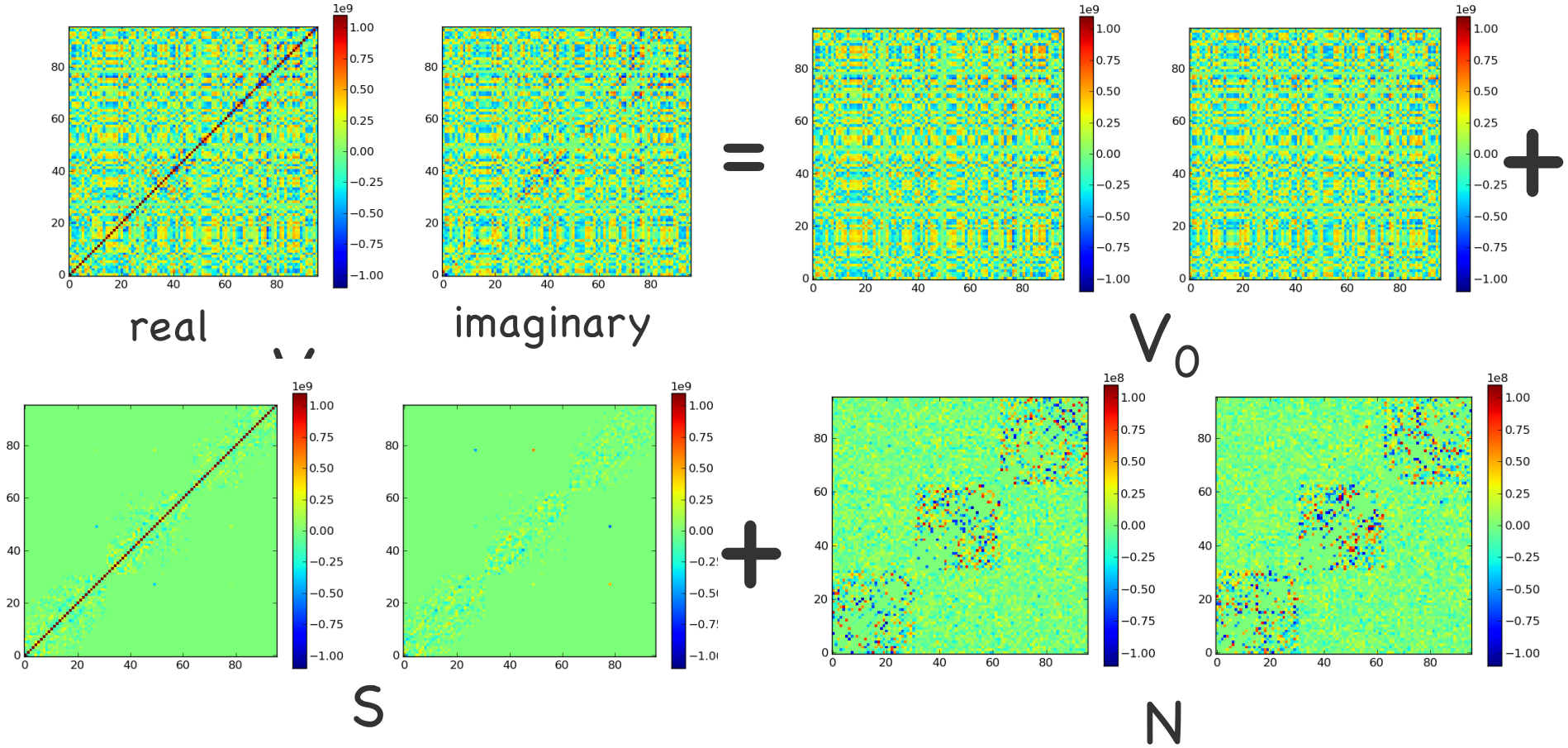
Bright source calibration(Absolute cal)

Method (2) Eigenvalue decomposition method

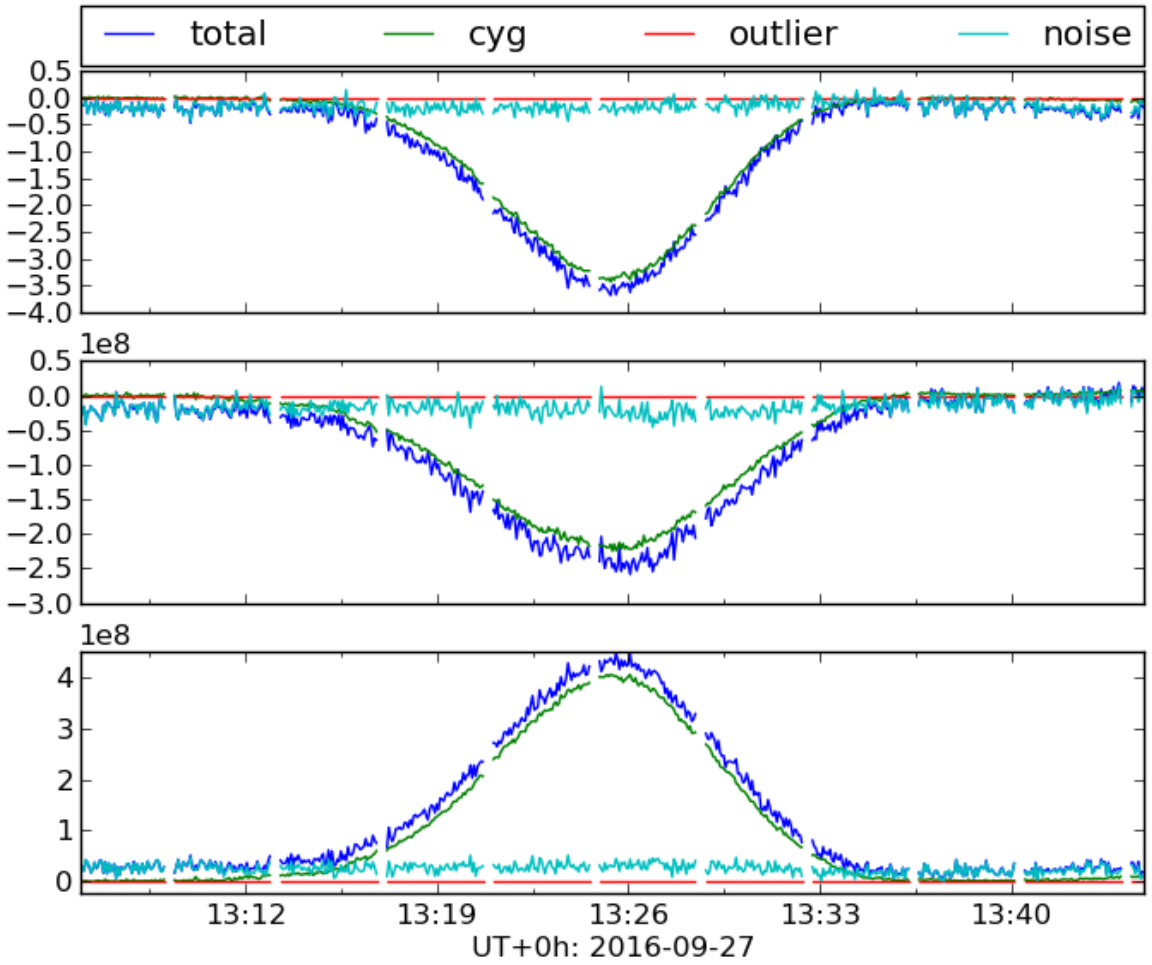
$$\frac{V_{ij}}{S_c} = G_i G_j^* + S_{ij} + n_{ij}$$

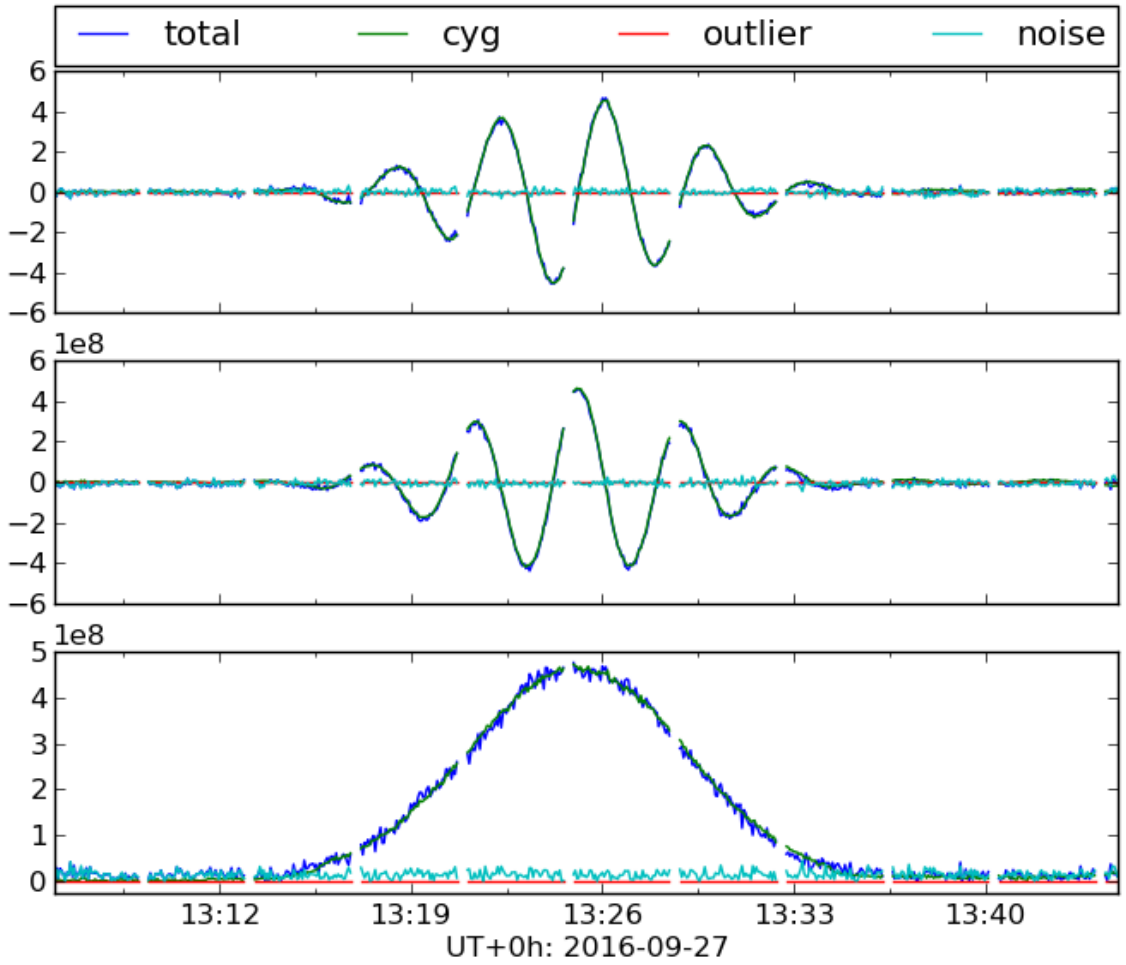
$$V = V_0 + S + N$$

Shifan Zuo, et al. AJ 157, 1

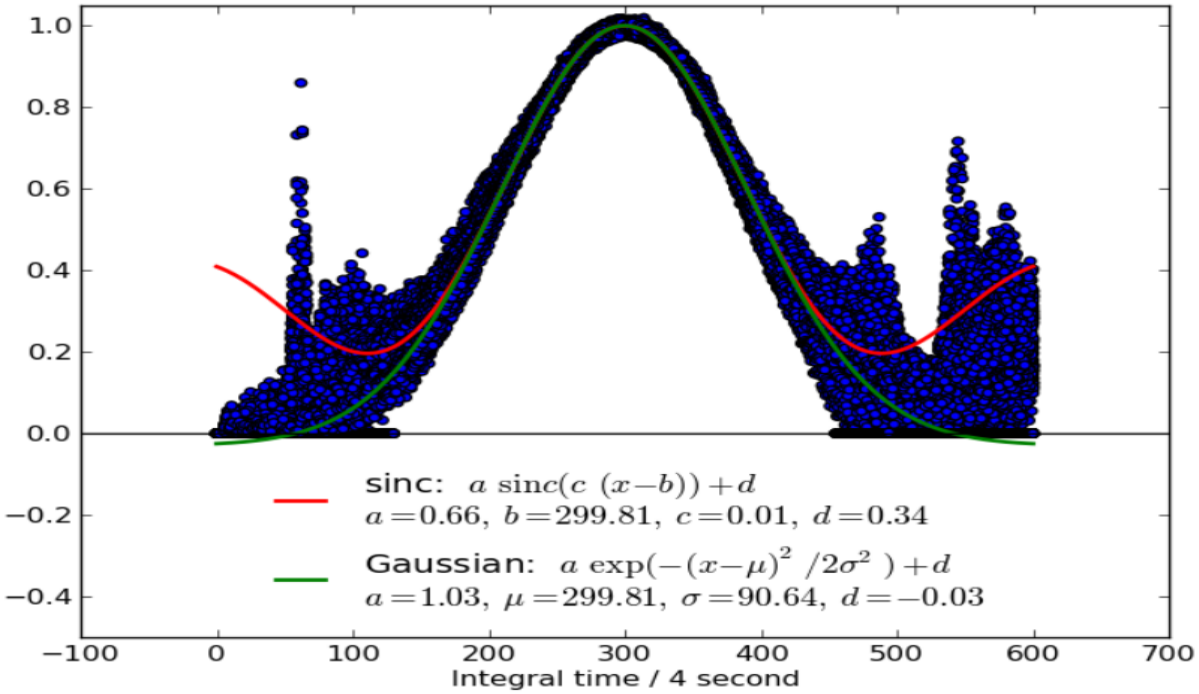


Eigenvalue decomposition method: fringe comparison

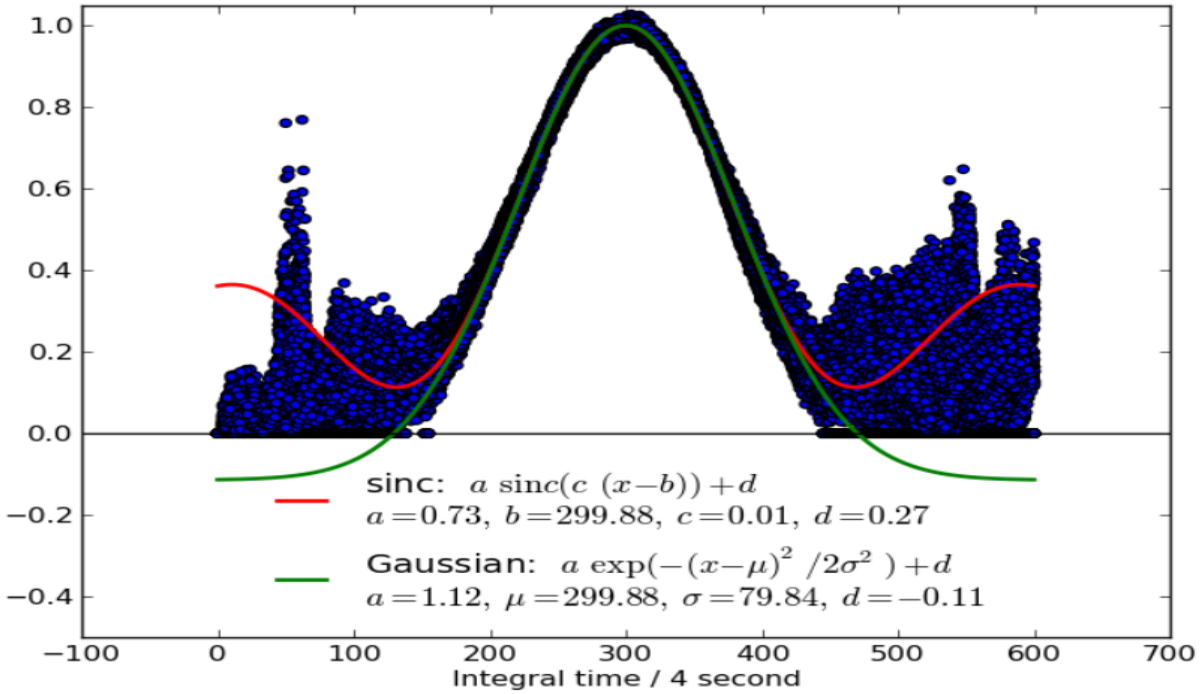




Solving antenna beam pattern

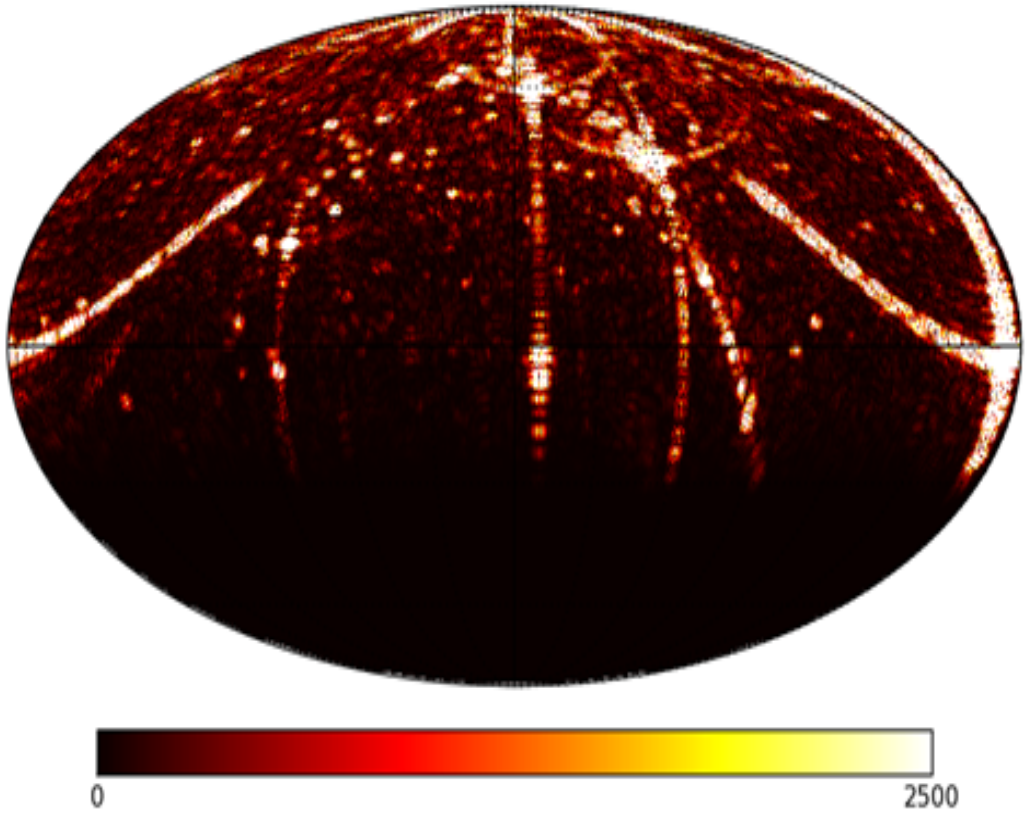


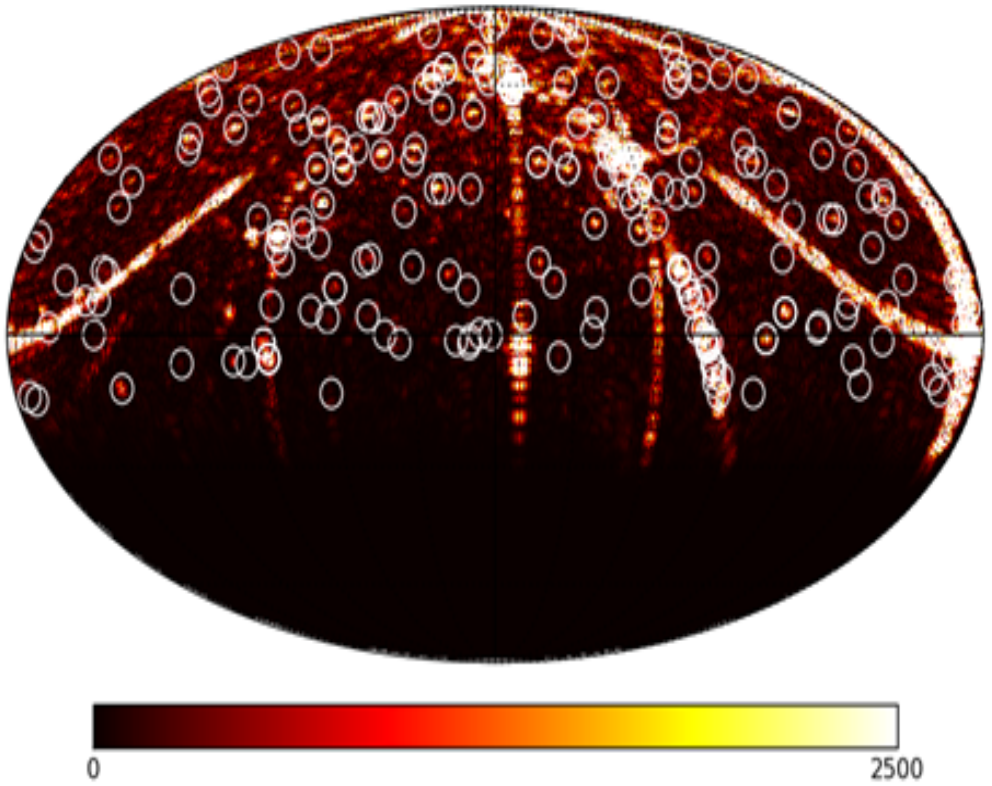
East-West pol, FWHM $= 3.7°$



North-South pol, FWHM $= 3.13°$

Map-making

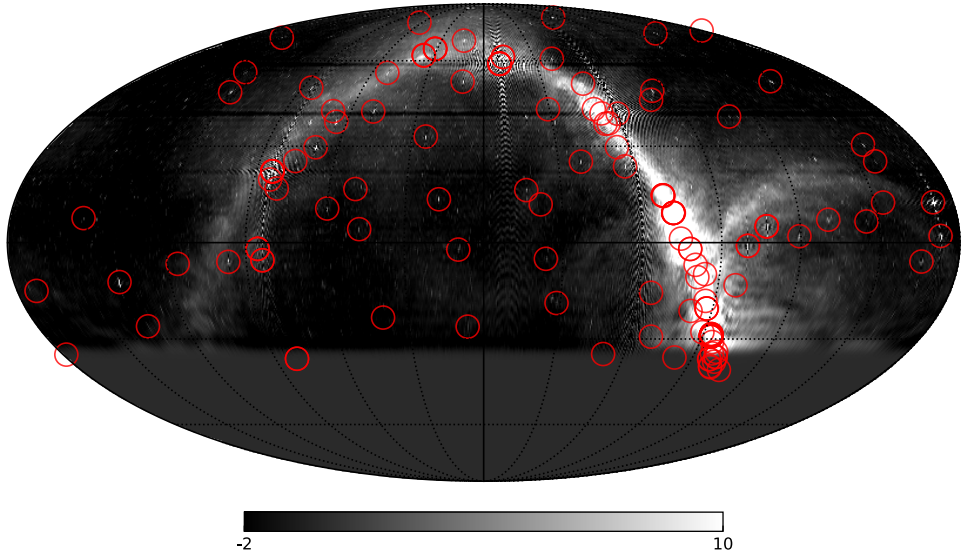




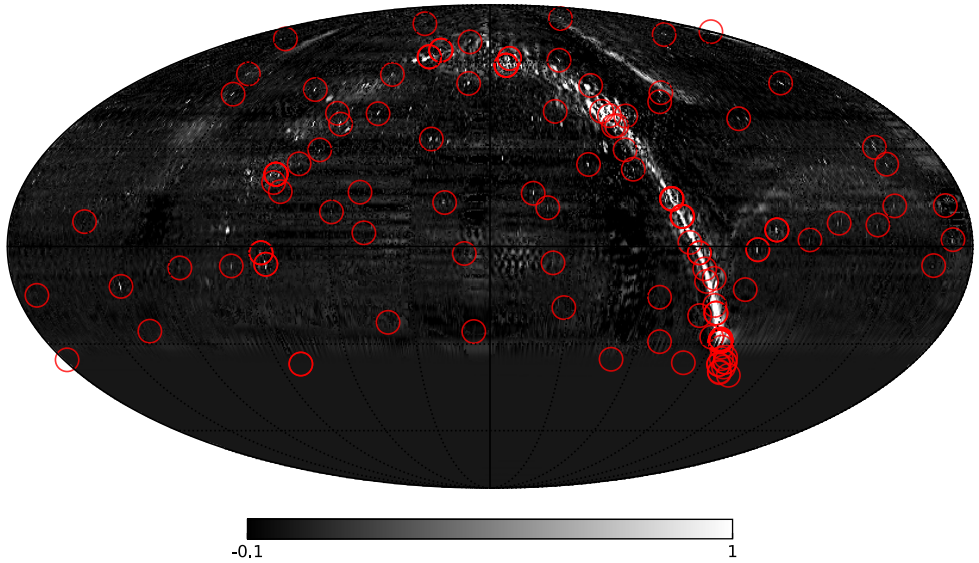
Sky image made by 3-day data of cylinder array, only 5 frequency channels around 750 MHz is used.

Map-making

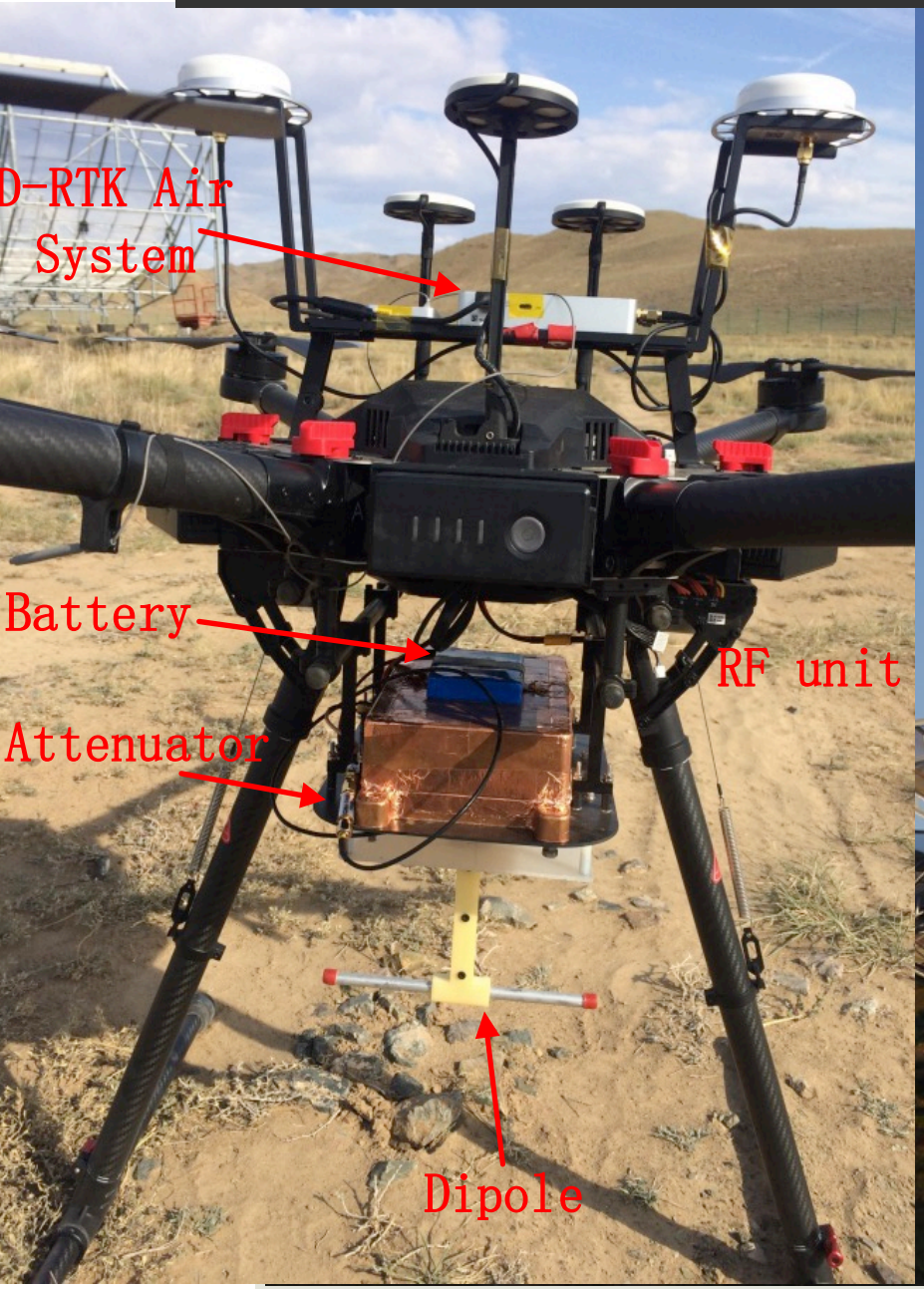
simulated imaging map



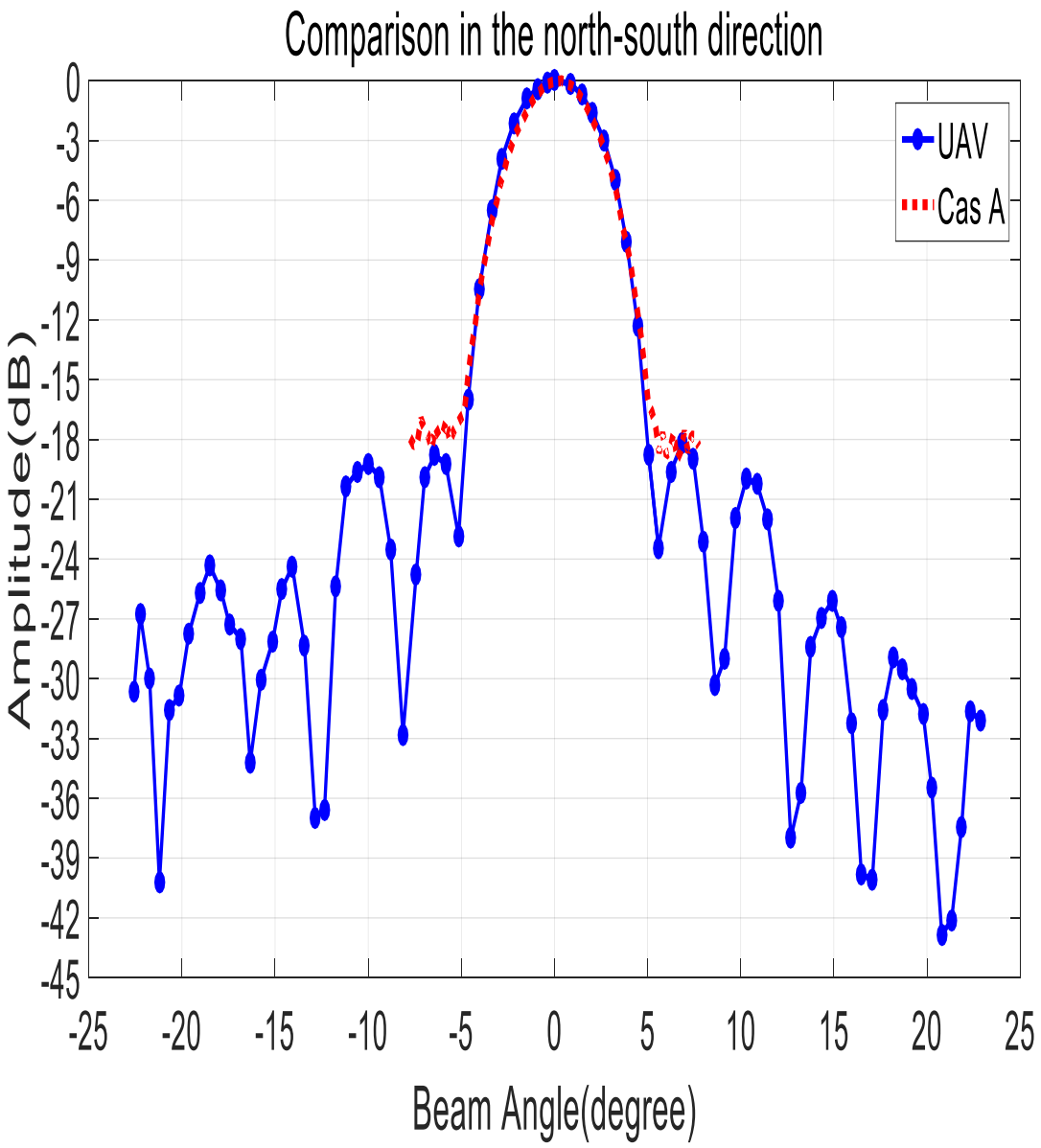
observation imaging map

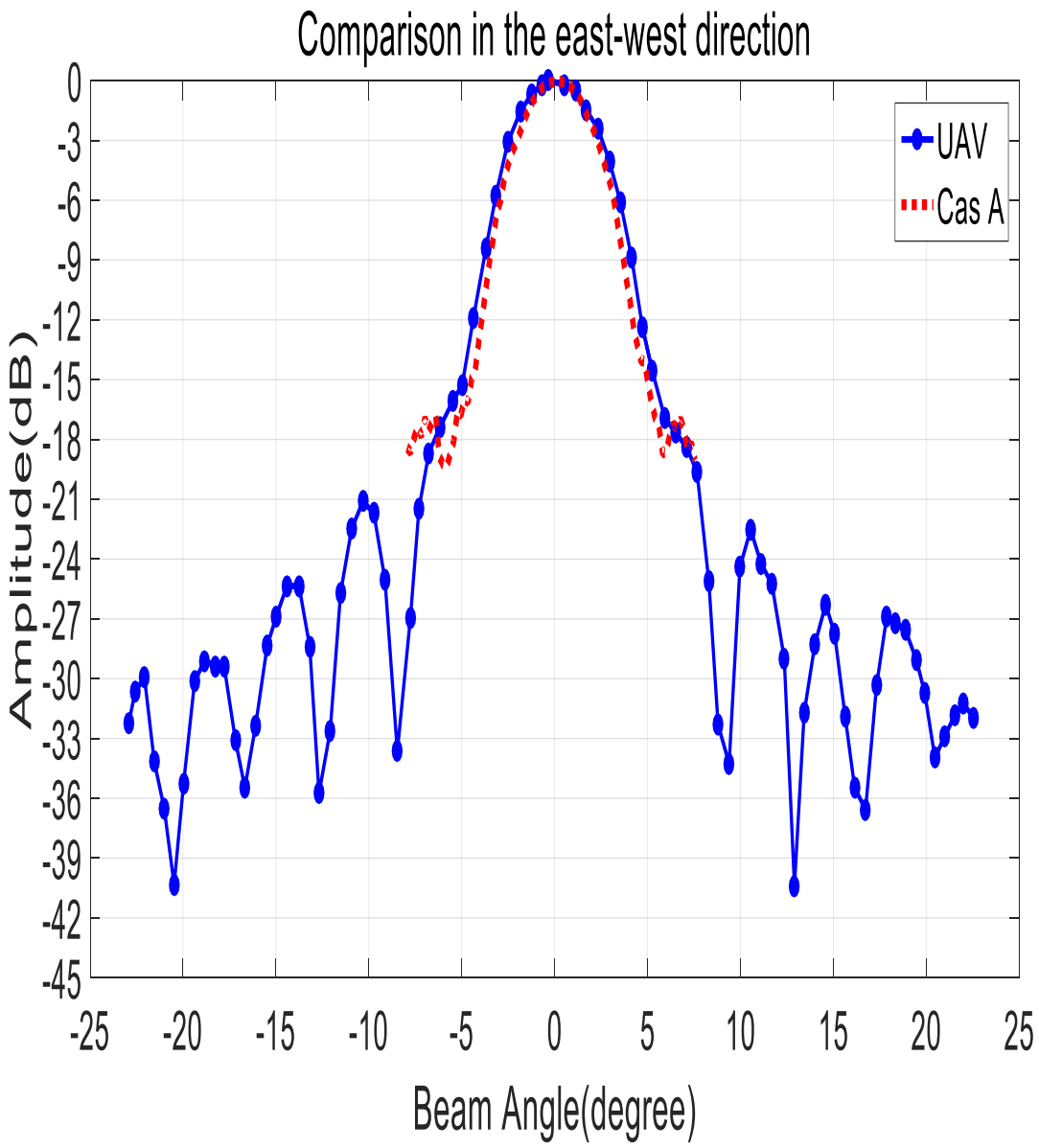


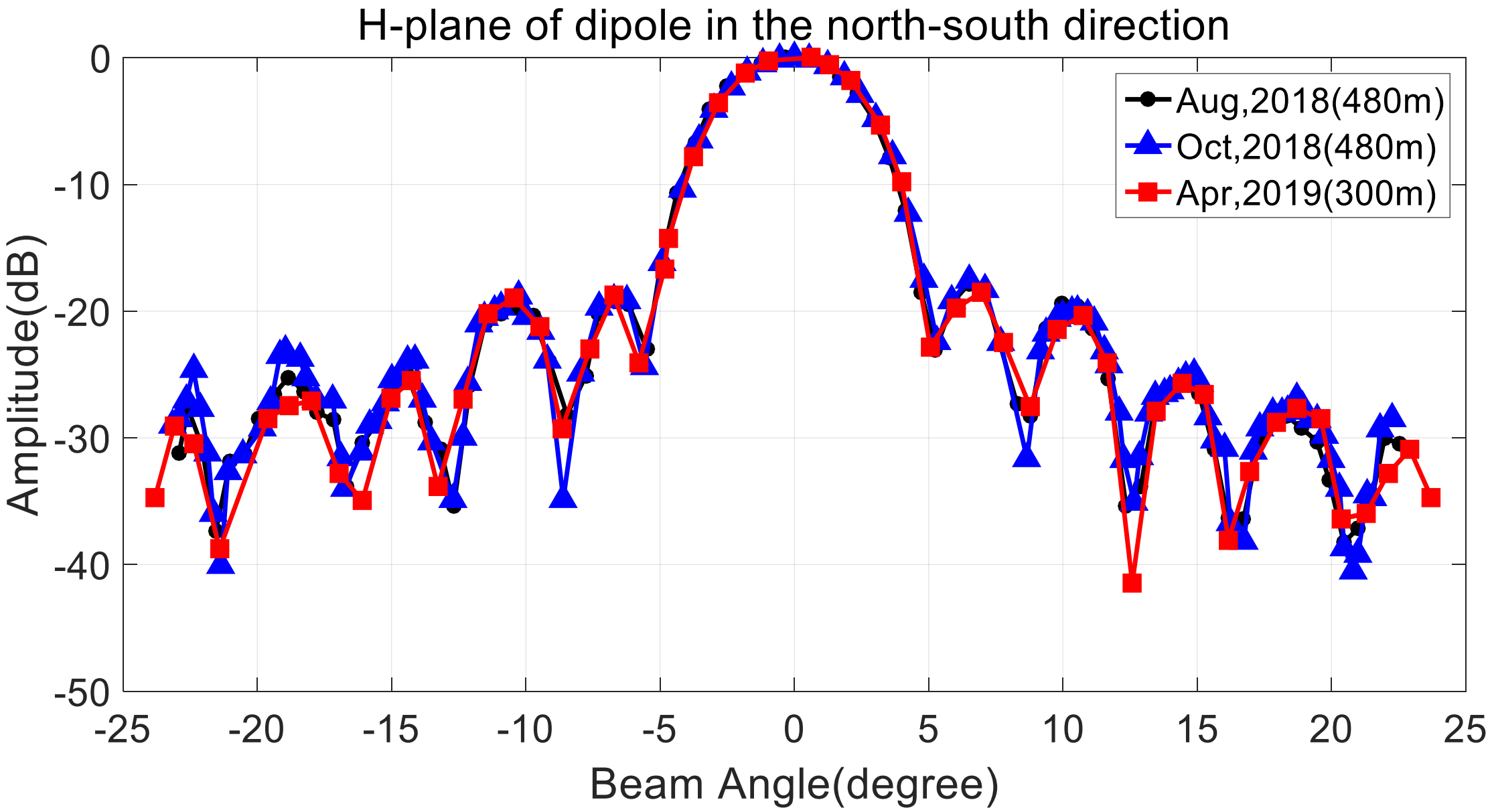
Beam measurement with Drone



Juyong Zhang et al., in preparation


Comparison in the north-south direction
UAV
Cas A
Amplitude(dB)
Beam Angle(degree)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-36
-39
-42
-45
-25
-20
-15
-10
-5
0
5
10
15
20
25


Comparison in the east-west direction
UAV
Cas A
Amplitude(dB)
Beam Angle(degree)
0
-3
-6
-9
-12
-15
-18
-21
-24
-27
-30
-33
-36
-39
-42
-45
-25
-20
-15
-10
-5
0
5
10
15
20
25

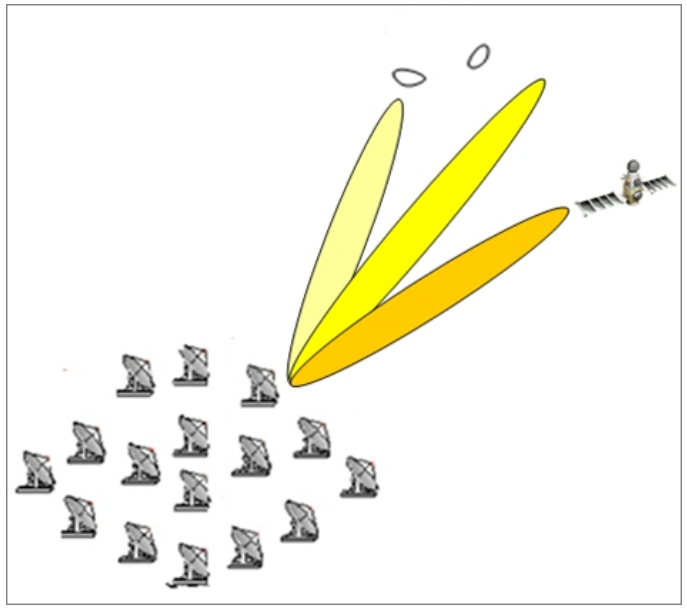

H-plane of dipole in the north-south direction
Aug,2018(480m)
Oct,2018(480m)
Apr,2019(300m)
Amplitude(dB)
Beam Angle(degree)
0
-10
-20
-30
-40
-50
-25
-20
-15
-10
-5
0
5
10
15
20
25

FRB search

- 32-channel FRB backend

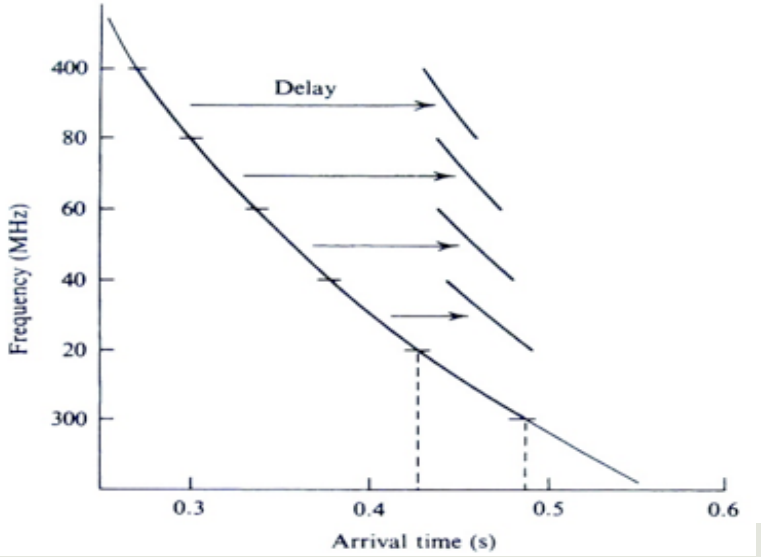
  --Install on site before the end of 2019

  - 2 snap2 boards, each with 16 RF input ports (working separately)
  - GPU de-dispersion

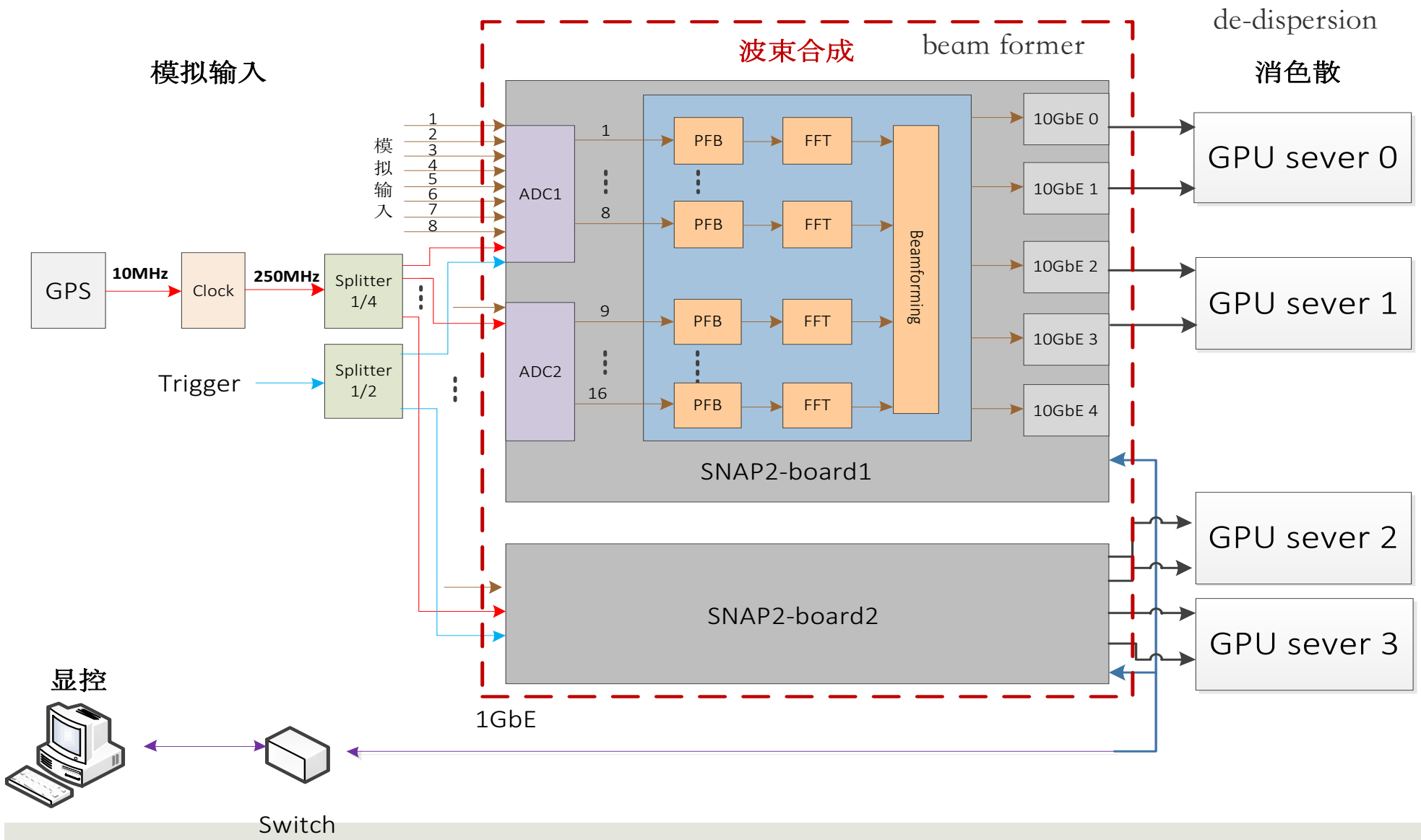


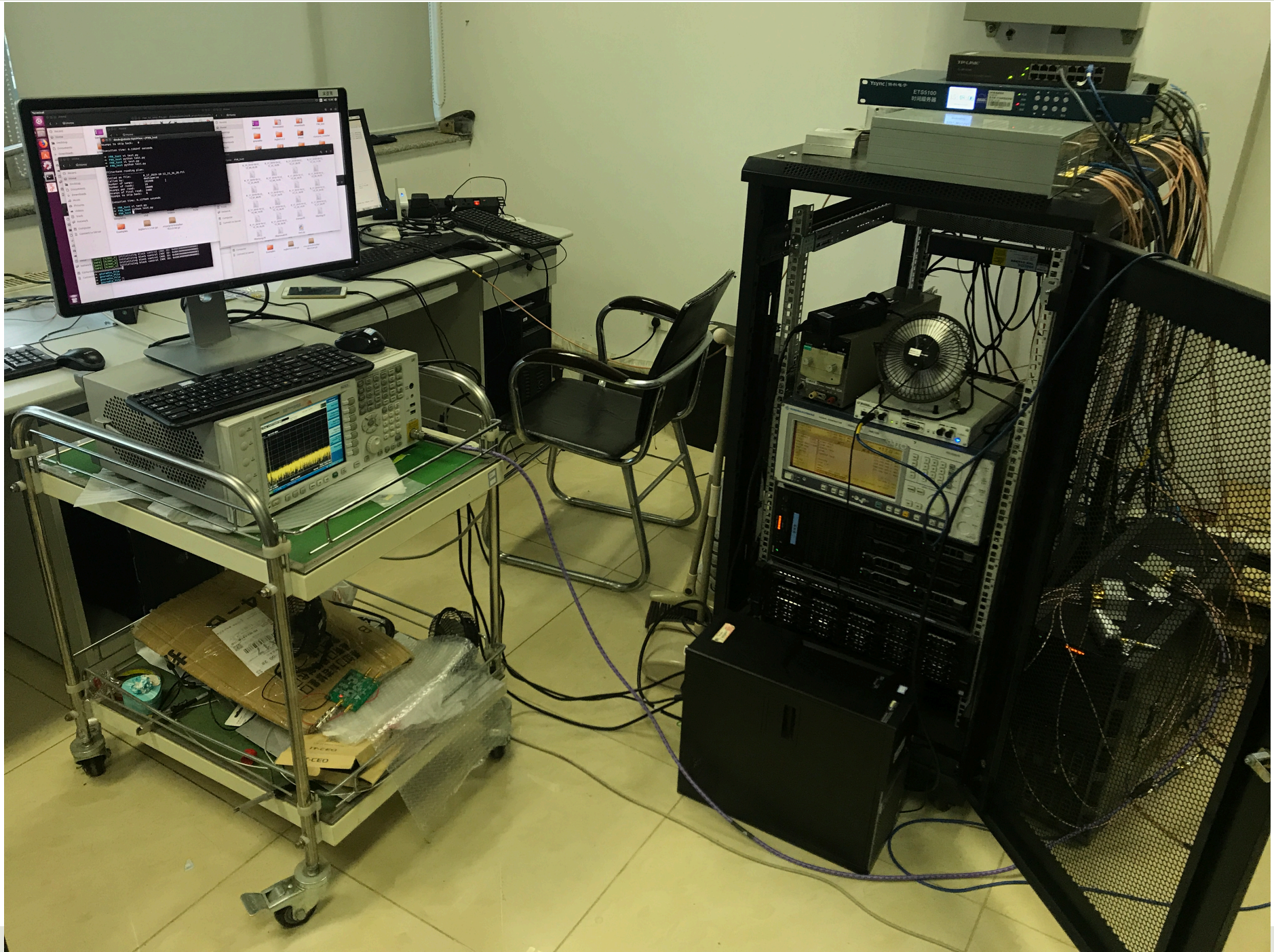
- 192-channel FRB backend

  --2020



Hardware setup




TP-LINK
Ysync
ETS5100

Summary

- The Tianlai pathfinders have been operating for 3 years, validation analysis in progress
- Prelimnary results indicate the arrays are stable
- FRB search backends coming soon

Thanks !