Meter to Decameter Wave Spectral Radio Heliograph

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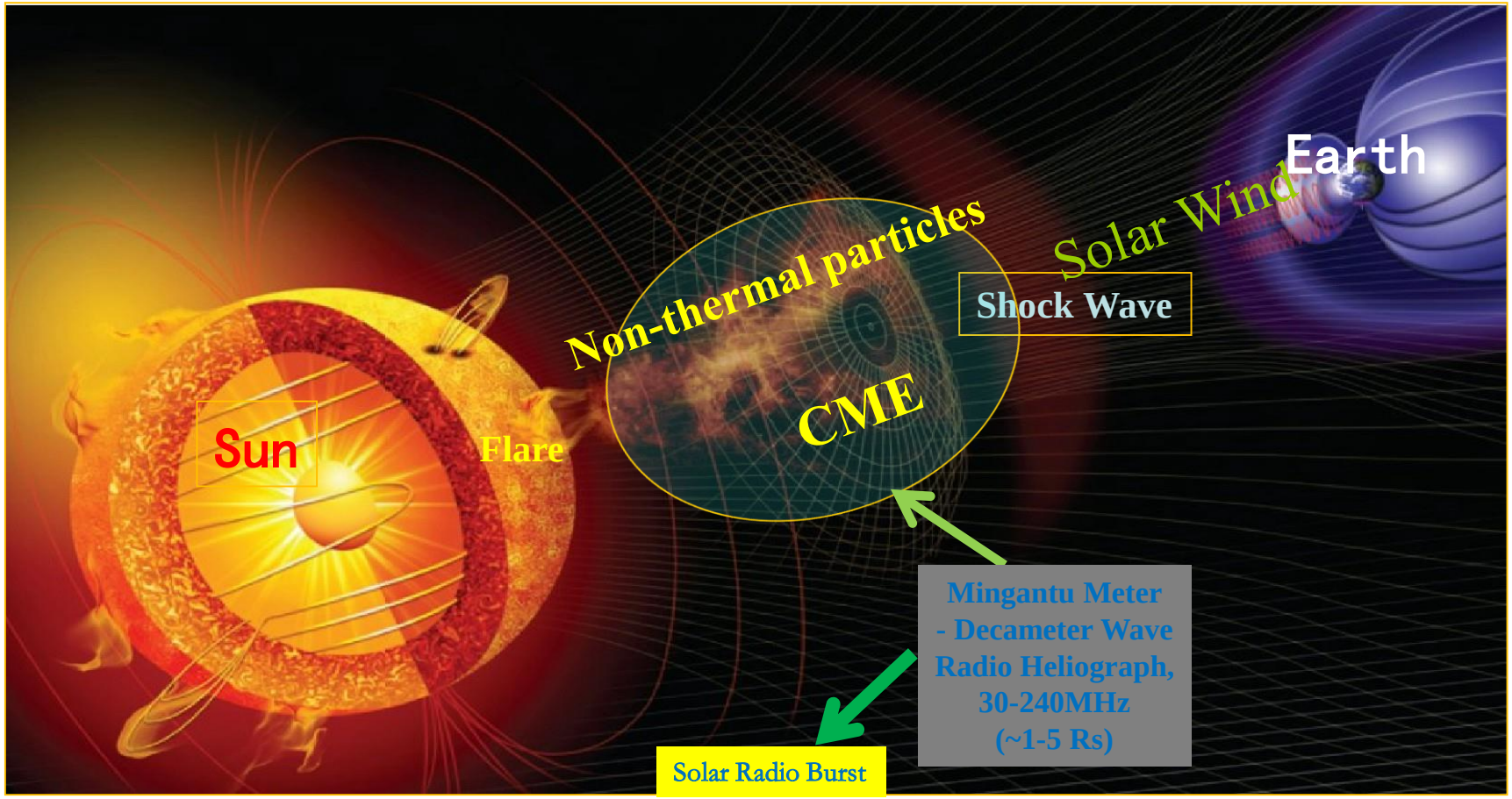
Outline

1. Scientific Objectives
2. Present Instruments
3. Specifications
4. System Design
5. Key technologies
6. Summaries

Scientific Objectives for the Solar-interplanetary sub-system of Meridian II project

With the terrestrial instruments, detect the solar intense activities, including the solar flare, CME, interplanetary shock wave, non-thermal particles, solar winds, etc. in the space between the solar surface to the Earth (0-215 $R_{\odot}$); study the disturbance, coupling mechanism, energy transfer mechanism of the interplanetary and terrestrial space impacted by the solar activities.

Meter-Decameter Wave Spectral Radio Heliograph



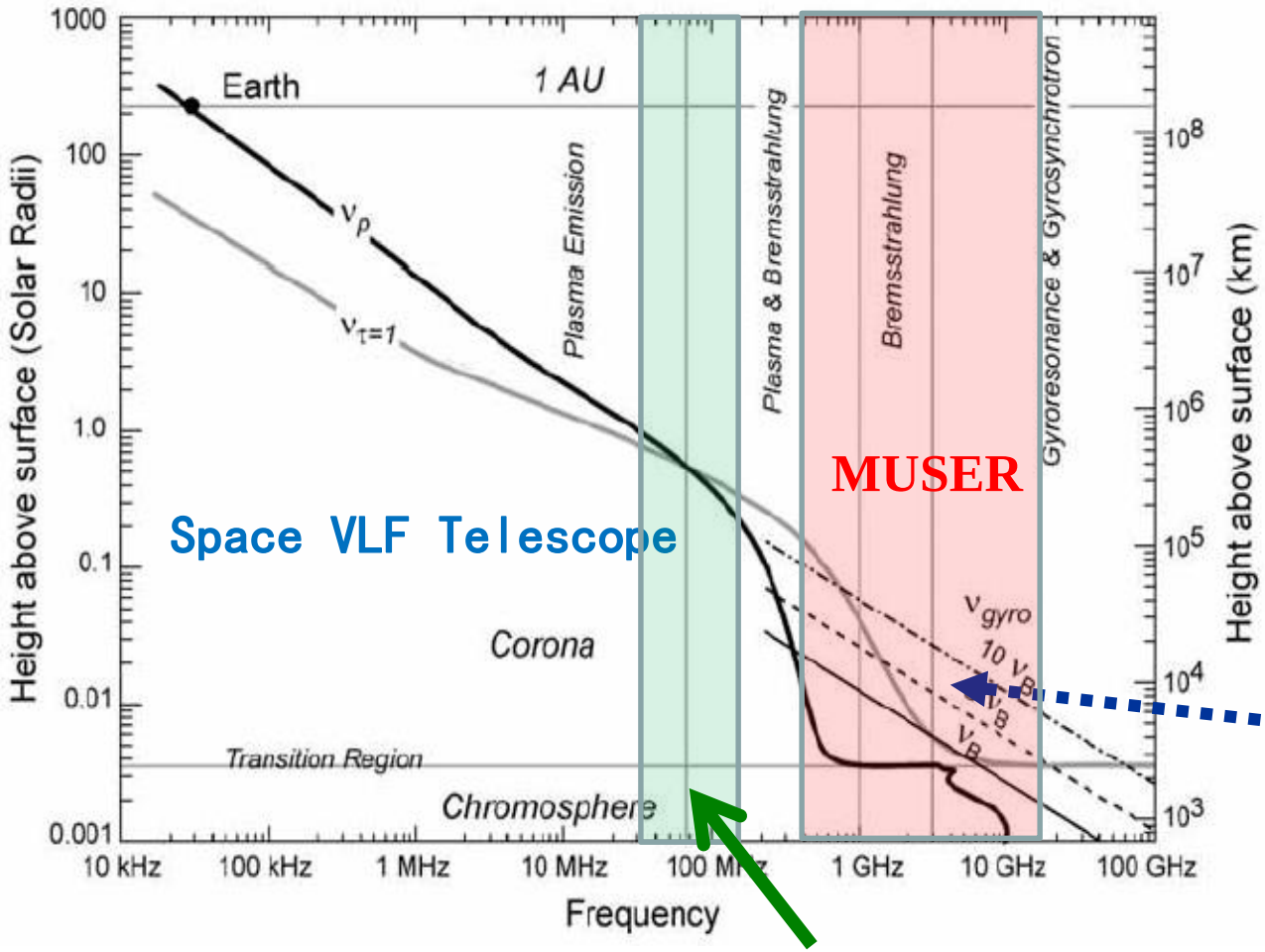
Project Significance

- Meter-Decameter Wave Spectral Radio Heliograph is an important part of the Solar-interplanetary sub-system of Meridian II project ;
- Combined with MUSER, it can achieve a solar radio spectral imaging system at the frequency range from centimeter to decameter.
- The system will be an solar radio detecting system with the capability of high-temporal, high-spectral and high-spatial resolutions in the widest frequency band. It can do the full monitoring for the disturbance source in interplanetary space.

Scientific Objectives

- So far, it is a big scientific gap in the world to dedicatedly observe solar radio bursts with high-performance images in the frequency range of meter and decameter wavelengths.
- This frequency is just covered the important space of CMEs and non-thermal particles' propagation, acceleration and evolutions, which strongly disturbs and impacts on the interplanetary and terrestrial space, and may trigger the disastrous space weather events.
- Therefore, it is most necessary to build a new solar radio telescope operating in the frequency of meter and decameter wavelength and with high temporal, spectral, and spatial resolutions.

Solar Radio Emission



$$\nu_p = 8.98\times10^3\sqrt{n_e}$$

$$\nu_{\tau=1} \approx 0.5 n_e T_e^{-3/4} L^{1/2}$$

$$\nu_B = 2.8\times10^6 B$$

（Gary，1999）

(1) Bremsstrahlung

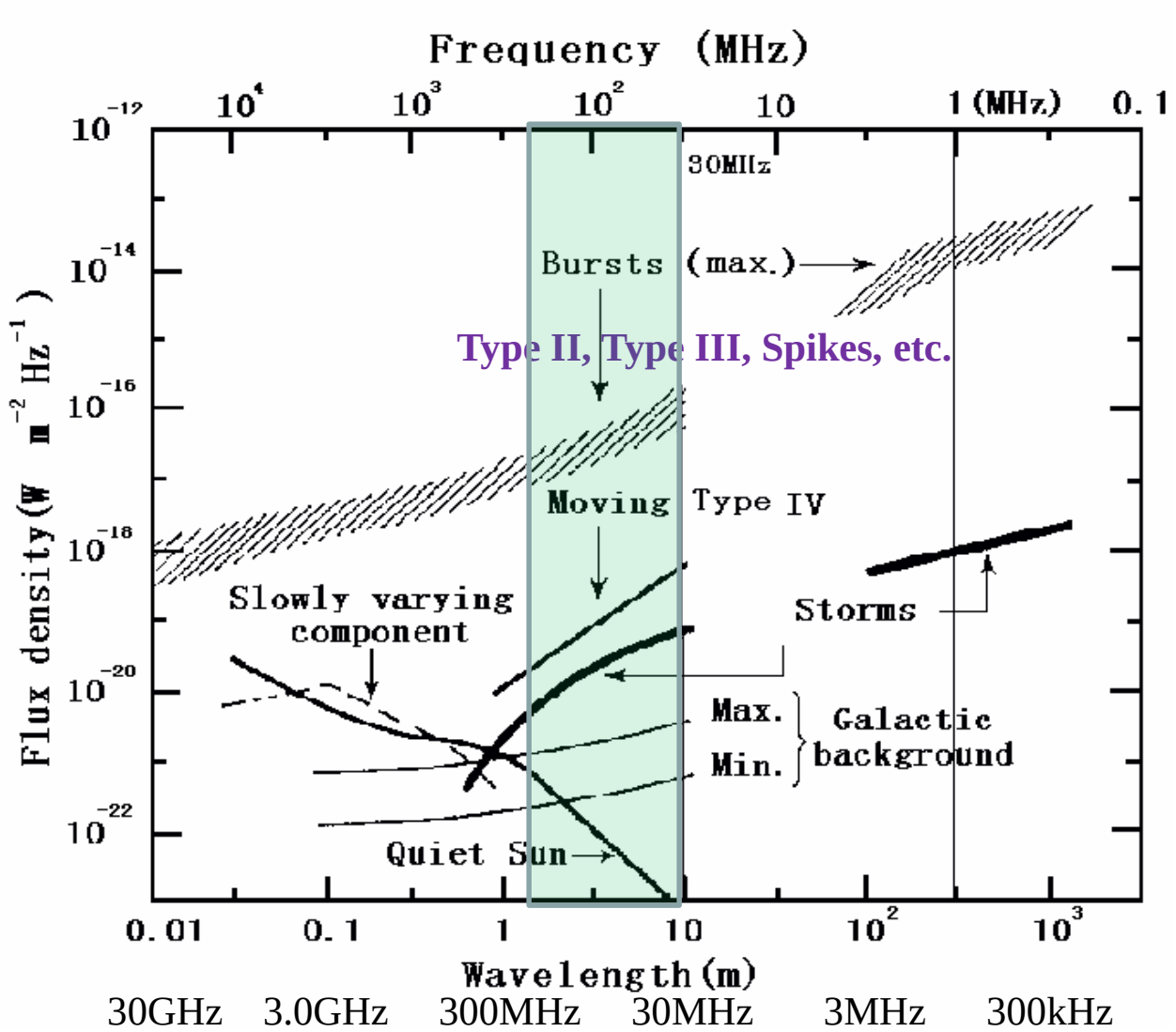
(2) Gyroresonance

(3) Coherent emission

★ Plasma emission

★ ECME

Solar and Galactic radio emission flux



Present solar radio heliograph

Instrument	Frequency	Time resolution	Frequency resolution	Polarization	Time
MUSER	0.4-2.0GHz 2.0-15.0GHz	25ms 206ms	25MHz 25MHz	R,L	2016
NoRH	17GHz 34GHz	100ms 100ms	33.6MHz	R,L	1984
SSRT	5.70GHz	100ms	-	-	1996 Upgrade
NRH	150-450MHz	100ms	10 freqs 0.7MHz	-	1987 Upgrade
GRAPH	40-150MHz	256ms	1MHz 1 freq	-	1997

Present solar radio imaging telescope

MUSER

1. **Ultra-wide Band**：0.40-15.0GHz
2. **High resolution**：Spatial, 1.4-51.6″，temporal, 25-200ms，frequency, 25MHz.
3. **High-speed spectral imaging**：584, imaging with ~200ms
4. **Dual-circular polarization**：L& R

Present solar radio imaging telescope

NoRH

SSRT

Present solar radio imaging telescope

NRH

Gauribidanur Radio Heliograph

Main Specification

- Frequency： 30MHz－240MHz
- Antenna ： 100 LPDA antenna
- Longest Baseline： 3000m
- Frequency Resolution：1MHz~5MHz
- Temporal Resolution：100ms
- Spatial Resolution：1.7’@240MHz－14.0’@30MHz
- Polarization： I、Q、U、V

Frequency：30MHz－240MHz

- Solar radio emissions below150MHz locate the area from1 to 5 Rs， where the solar events including CME、non-thermal particle and solar wind are produced and accelerated, it is crucial to systematically monitor this area.
- Covering the full frequency band that can be observed on the ground with the Daocheng Circular Array together, the overlap frequency can be used to mutually testified

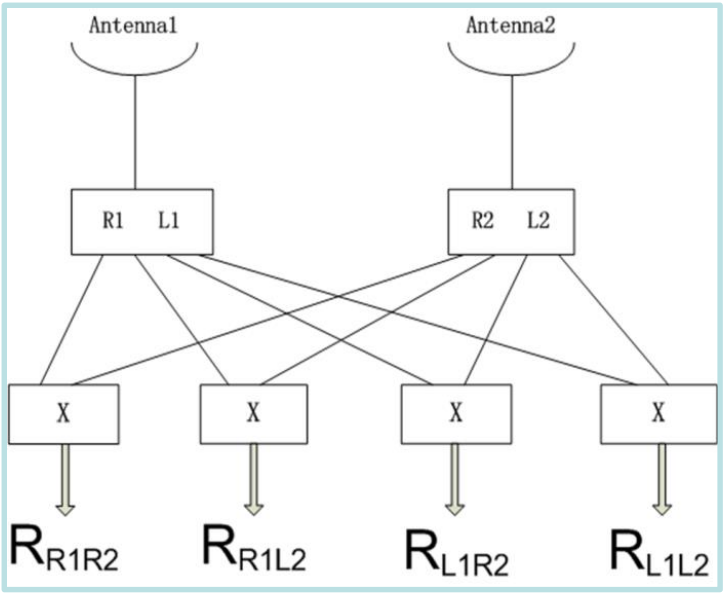
Antenna

- LPDA, Most used and mature；
- Based on the simulations, 100 antennas are enough to get good images;
- Simple mechanism, cheap,.

Polarization： I、Q、U、V

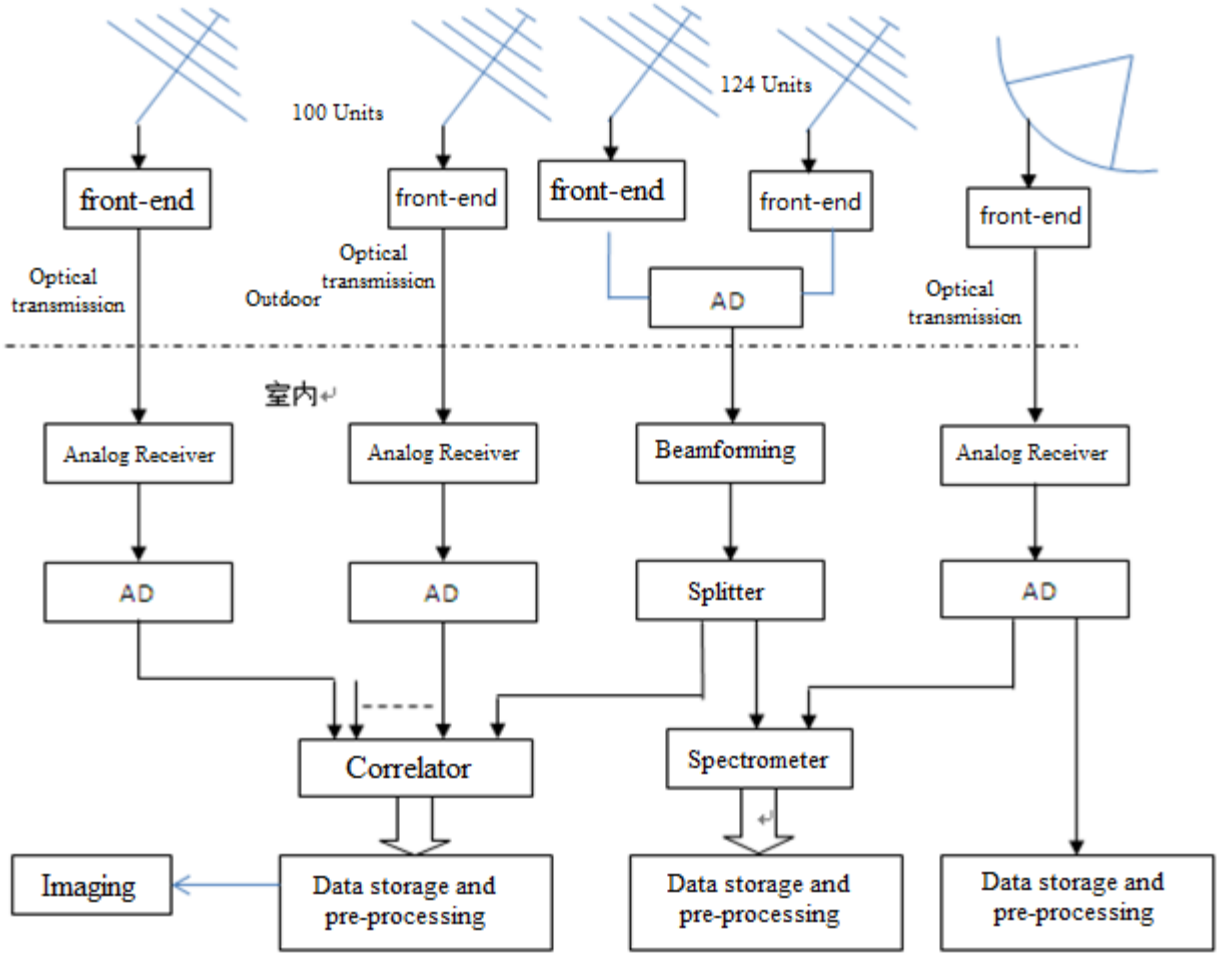
- **For crossed linearly polarized feeds**

$$
\begin{aligned}
v_{pp} &= \tfrac{1}{2} g_{ip} g^*_{kp} (I + Q\ \cos 2\chi + U\ \sin 2\chi), \\
v_{pq} &= \tfrac{1}{2} g_{ip} g^*_{kq} ((d_{ip} - d^*_{kq}) I - Q\ \sin 2\chi + U\ \cos 2\chi + jV), \\
v_{qp} &= \tfrac{1}{2} g_{iq} g^*_{kp} ((d^*_{kp} - d_{iq}) I - Q\ \sin 2\chi + U\ \cos 2\chi - jV), \\
v_{qq} &= \tfrac{1}{2} g_{iq} g^*_{kq} (I - Q\ \cos 2\chi - U\ \sin 2\chi),
\end{aligned}
$$



- 4 cross-correlations can be used to measure the antenna polarization performance;
- Decrease the crosstalk requirement of antenna polarization；
- For the signal with polarization unknown， 4 cross-correlations can used to measure the full stokes parameter, I, Q, U, V;

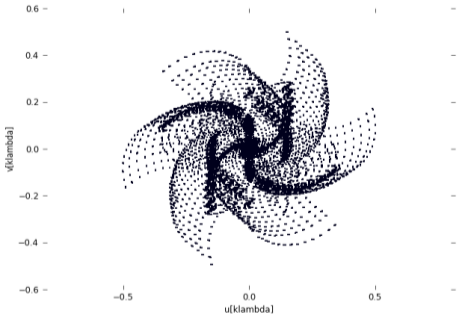
System Composition

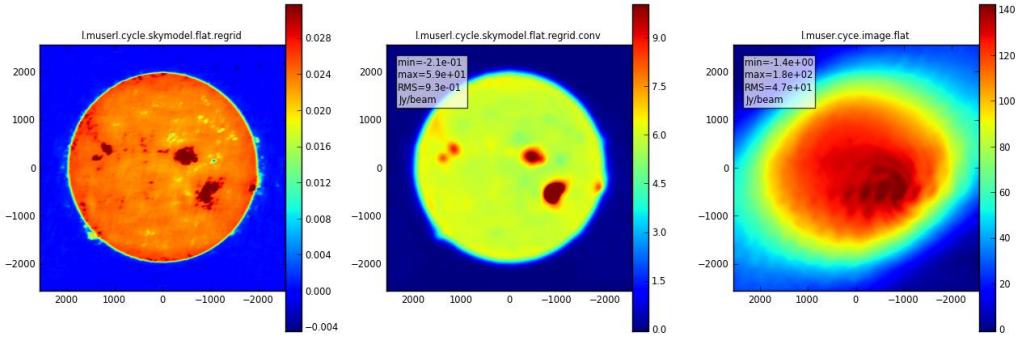


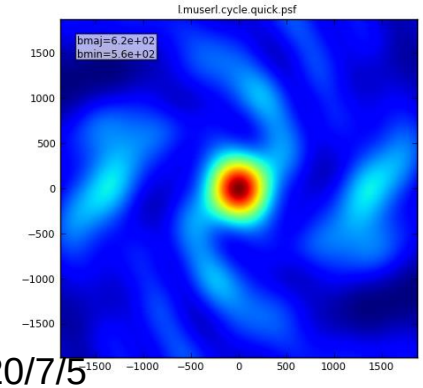
- 100 LPDA;
- Calibration unit (124 LPDA), also used as spectrometer;
- 124 LPDA, beam-forming。

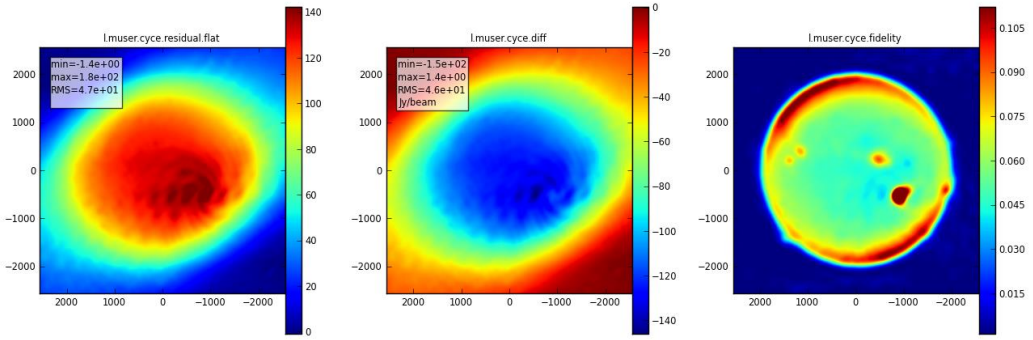
Array Configuration

- Design principle：UV coverage，Beam Characteristic，Image quality ，Engineering Implementation；



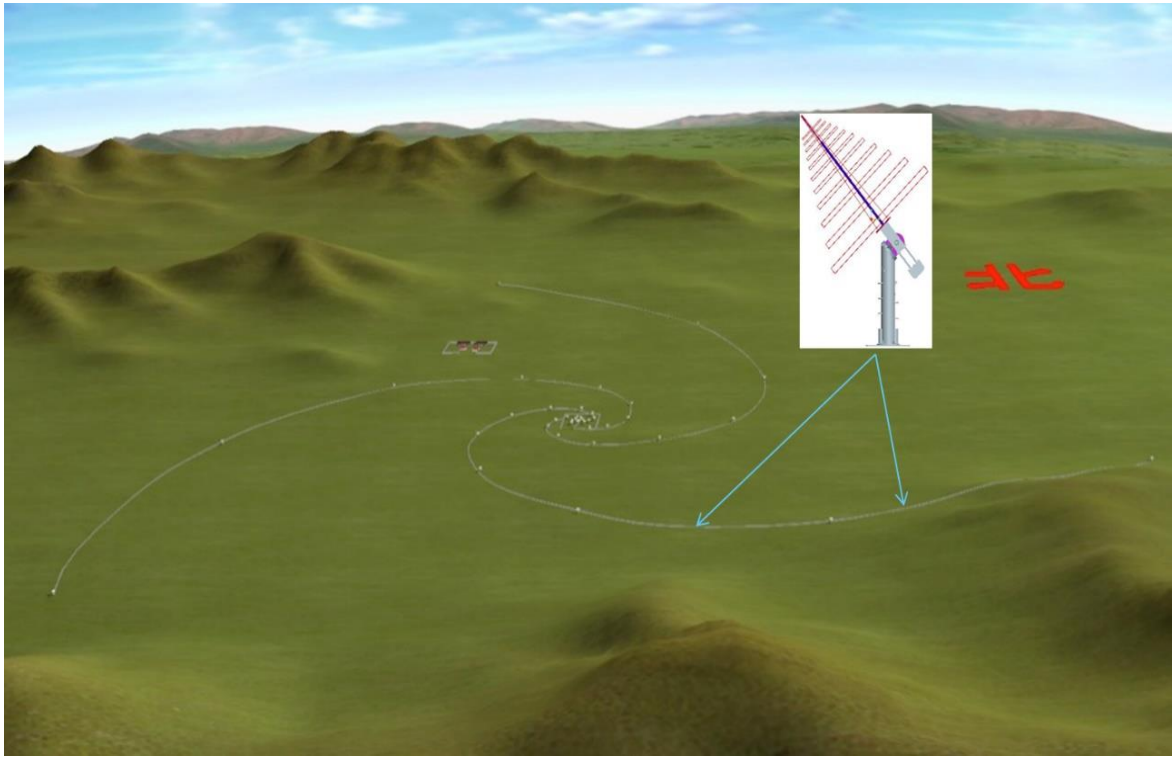


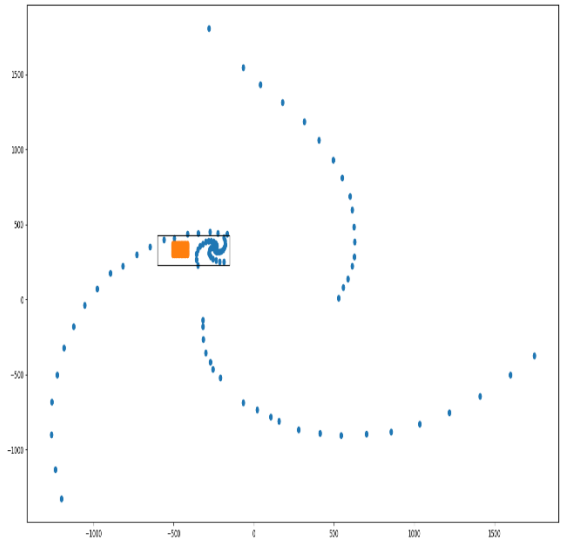




Array Design

- Fully take advance of the present location and condition。



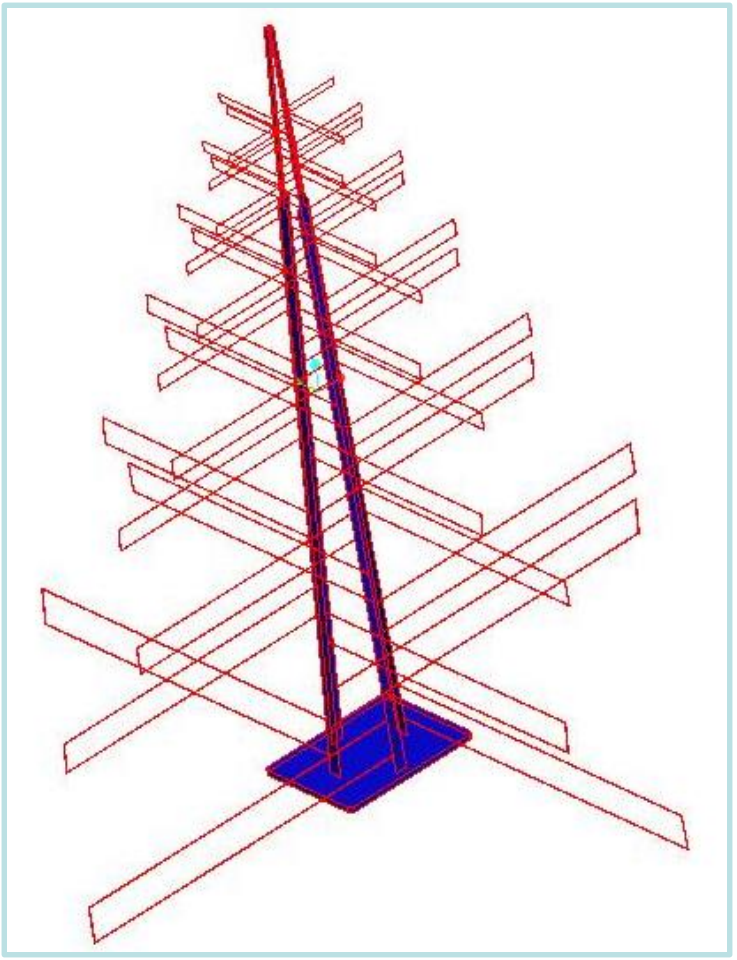


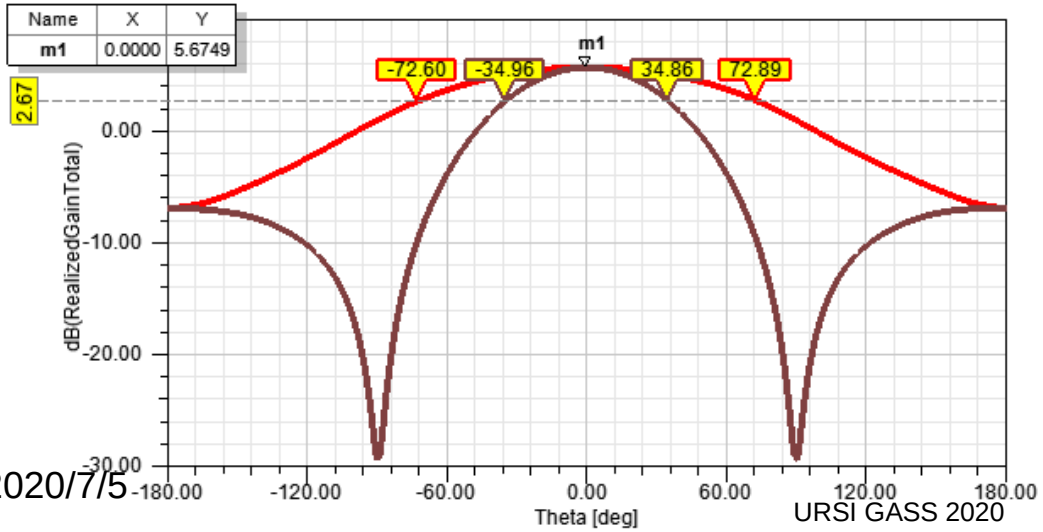
Array Configuration

Antenna Design

- Antenna：LPDA
- Frequency：30—240MHz
- Polarization：Dual-linear
- Gain：≥5dB（50MHz以上）
- VSWR：≤2.5
- Right ascension ：-95°～+95°
- Decline：-30°～+30°

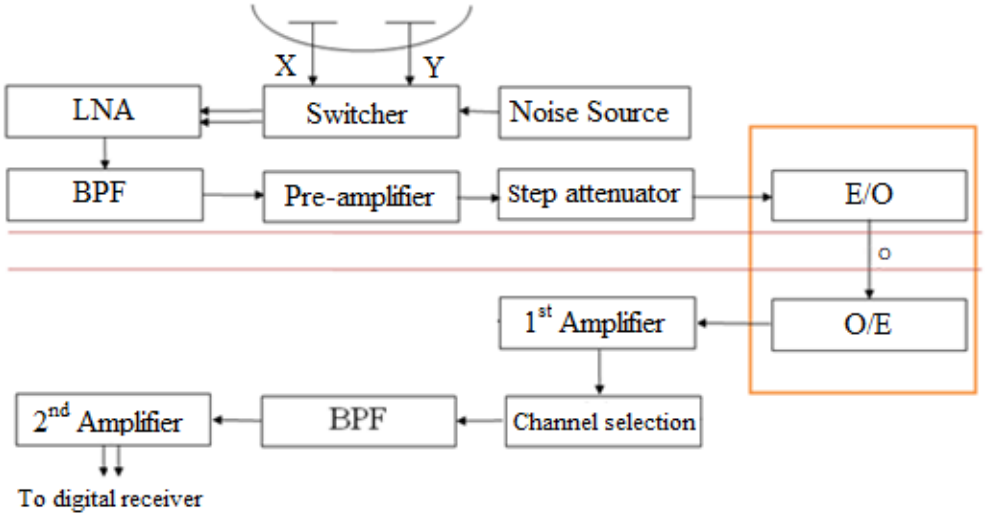
L×W×H=3.0m×3.0m×3.0m，much smaller than the half-wavelength antenna





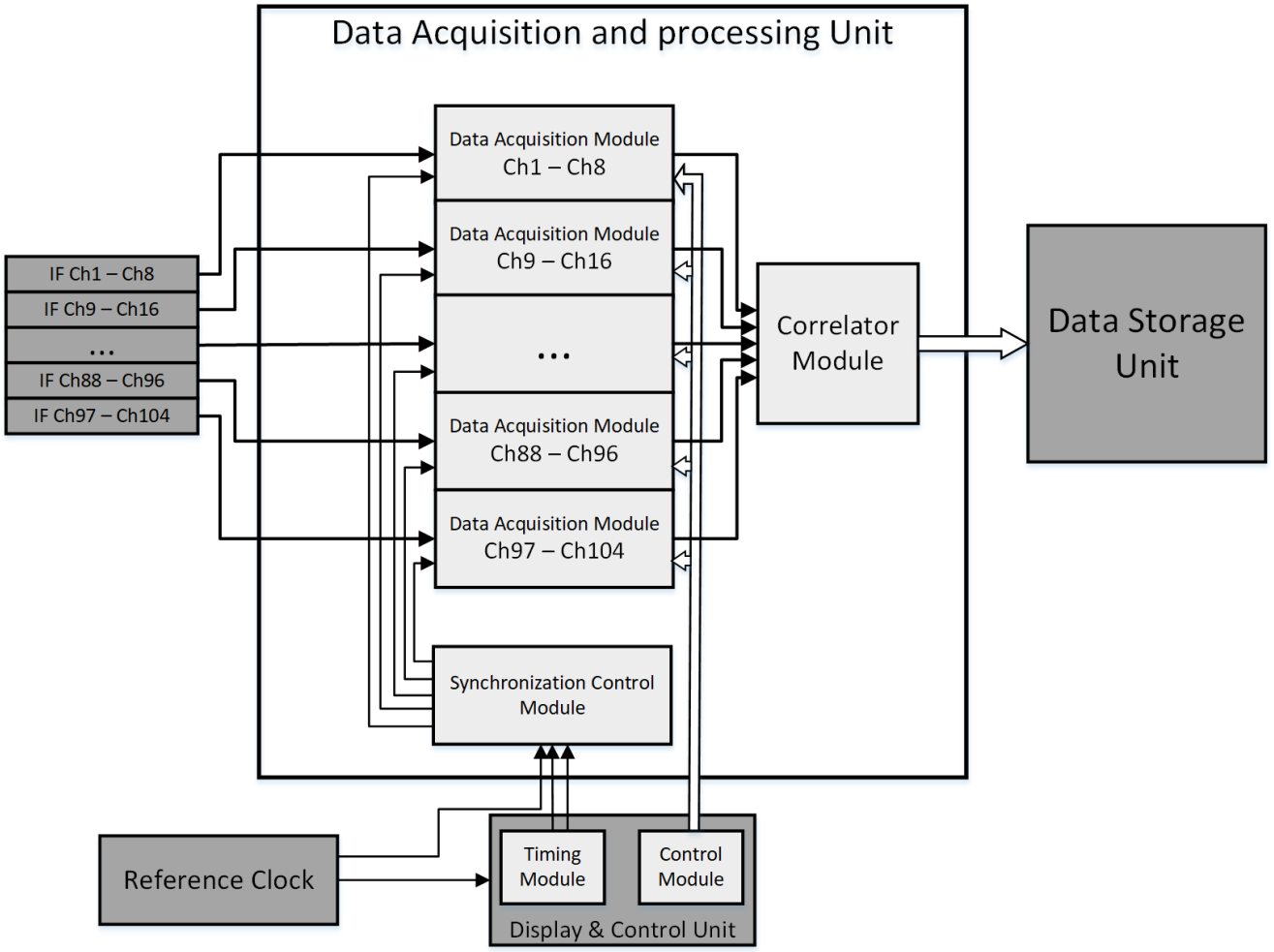
50MHz

Antenna receiver design



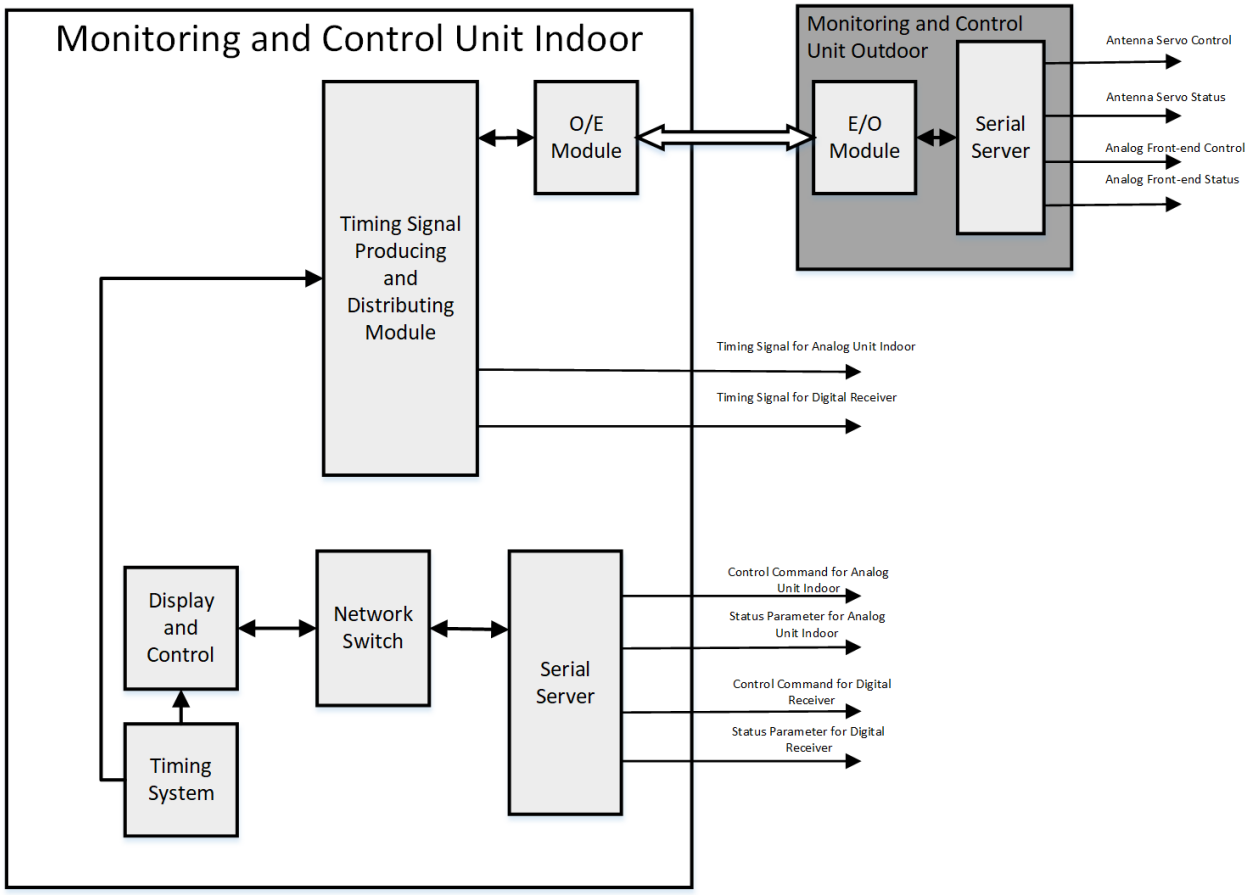
- Frequency：30MHz ~ 240MHz
- LNA NF：< 1.5dB
- IF band：~100MHz
- Isolation：≥70dB
- Flatness ：±1.5dB
- Attenuator: 30dB, adjustable

Digital Receiver Design

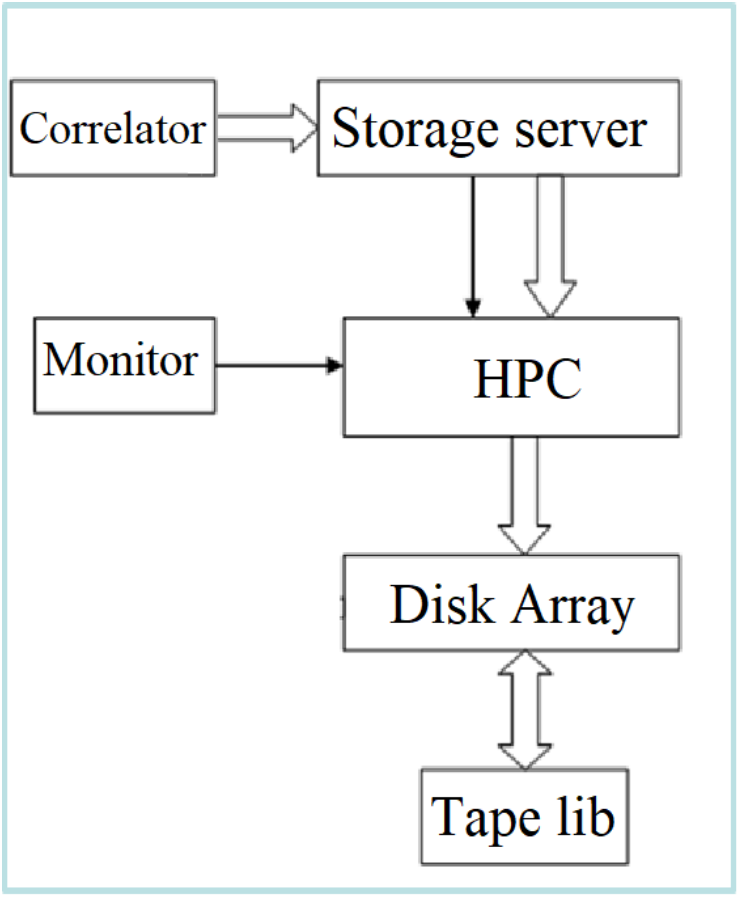


- **AD Acquisition： AD, BF filter, Fringe stop, 2bit quantization, Delay compensation.**
- **Synchronization Module: Sampling clock.**
- **Correlator module：4 correlator， Cos output, Sin output.**

Monitoring system

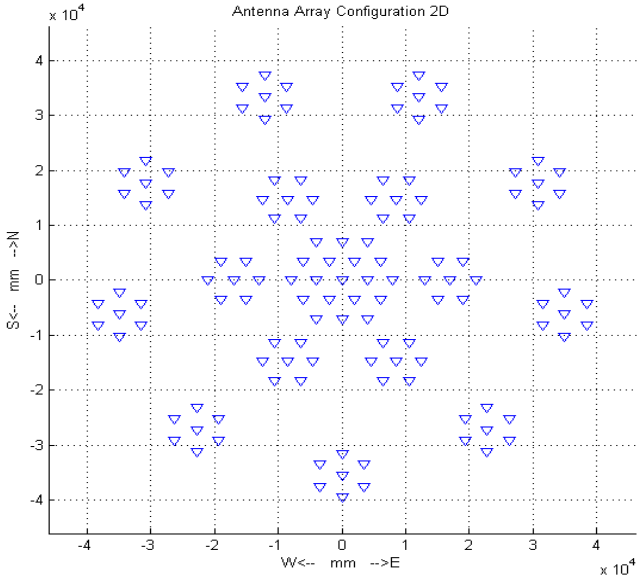


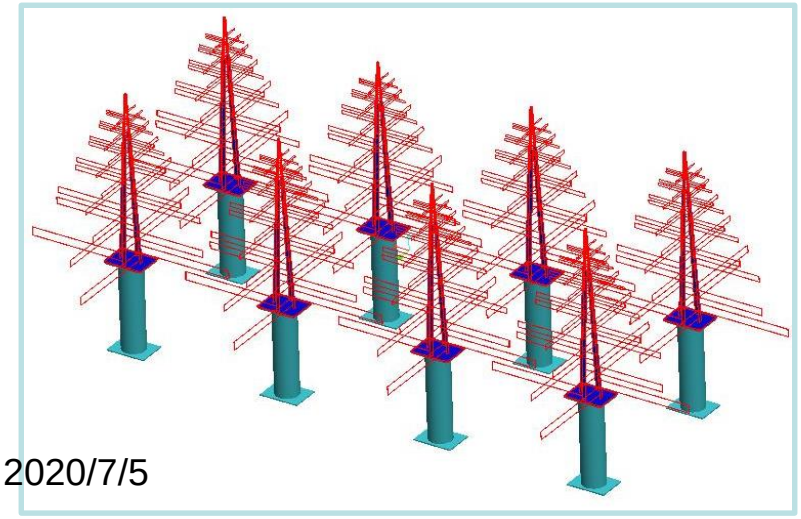
Data Processing Unit Design



1. Storage server
2. Monitor
3. HP computing server。
4. Harddisk array
5. Tape library

Calibration Unit Design





- 124 LPDA, 16 groups;
- 7 antenna summing，improve gain;
- Without tracking。

MUSER OS

```
d-10-145-200-28:bin yyh$ ./museros
Environment file: /Users/yyh/museros/resource/xml/system.xml

    __  ______  _____  ___________
   /  |/  / / / / ___// ____/ __ \
  / /|_/ / / / /\__ \/ __/ / /_/ /
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Version 1.0.0-REL (r1)
Compiled on: Wed 2016/2/8 12:39:00 UTC
Current IPython Version: 4


Muser <1>:
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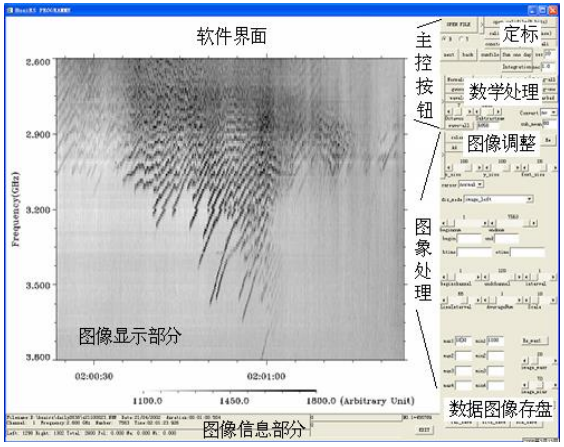

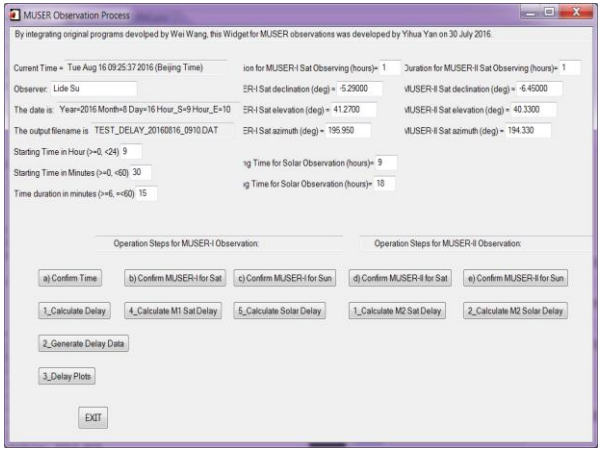

Observation Mode

Order	Observation Mode	Description	Temporal	Detection Area	Frequency
1	Normal Obs mode	Full frequency band, full time	second	0-5$R_{\odot}$	30MHz-240MHz
2	Frequency Selection mode	Frequency selection	second	0-5$R_{\odot}$	30MHz-240MHz Certain Frequency
3	Night Obs mode	Observe radio source for calibration and difference sciences	second	Radio sources	30MHz-240MHz

Data Archive

Level	Data name	Description	Format	Time resolution	Data Volume（MB）	Online or not?	Produced by data center?
0	Image raw data	Raw output，visibility, time, spectrum	Self-define	1 min	2TB	No	No
0	Spectral raw data	Raw output, time, spectrum	Self-define	Each min	1GB	No	No
1	Standard image format	Normal data format，time、visibility	FITS	5 min	1GB	No	No
2	Image production	Customer data，time、solar radio image	FITS	5 min	3.6GB	Yes	No
2	Spectral production	Customer data、time、spectrum	FITS	Each min	1GB	Yes	否

Thanks!