The Tianlai Project

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The Tianlai （Heavenly Sound) Project: 21cm intensity mapping experiment in China

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

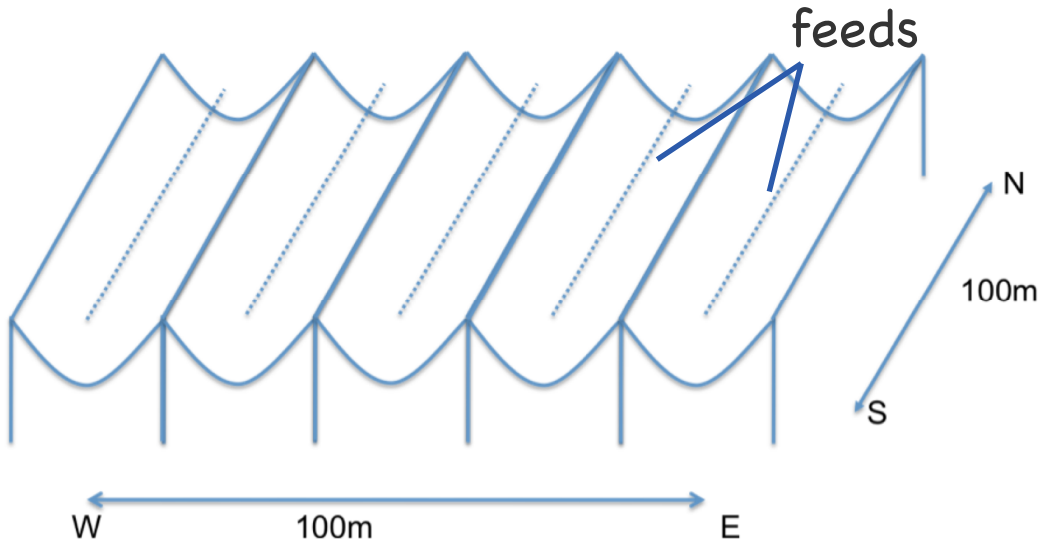
The Collaboration in China (mainland):
Science: NAOC, XAO Hangzhou Dianzi U
Technology: Institute of Automation, CETC-54, Hangzhou Dianzi U

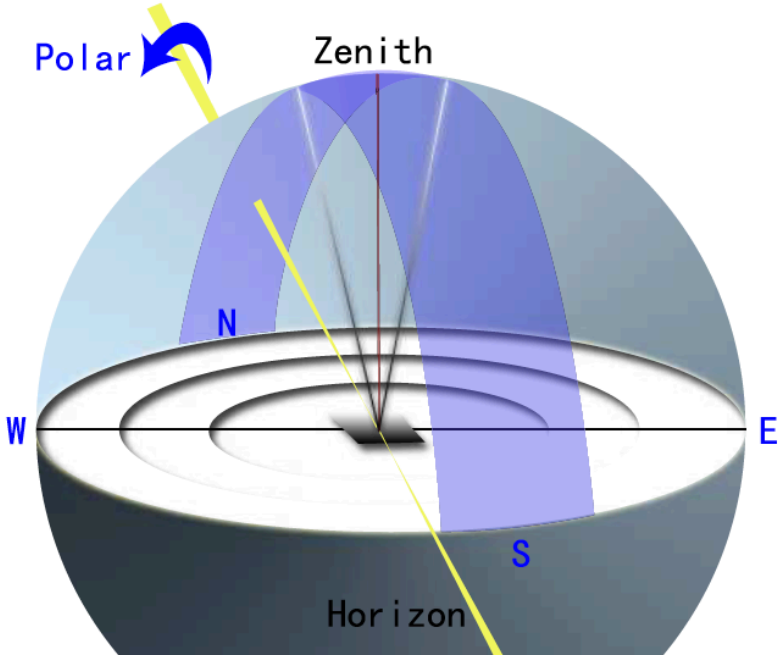
Tianlai Collaboration
NAOC: X. Chen, H. Shi, H. Tian, F. Wu, Y. Wang,
CITA: U.L. Pen
CMU: J. Peterson
FNAL: J. Marriner, A. Stebbins
Hangzhou Dianzi Univ: Z. Chen, J. Zhang
IRFU-CEA: C. Magneville, C. Yèche
LAL/IN2P3: R. Ansari, J.E. Campagne, M. Moniez
Obs. Paris: P. Colom, J.M. Martin
Univ. Wisconsin: P. Timbie

Dedicated Telescope: Cylinder?

cylinders:

CHIME (Canada)
Tianlai (China)





instant field of view

The Pittsburgh Cylinder Experiment

See also Ansari and Mechel-Martin's talk on the BAOradio experiment

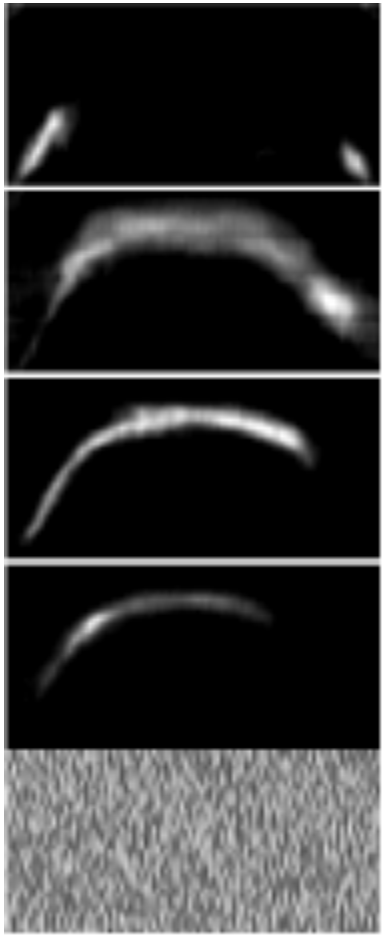
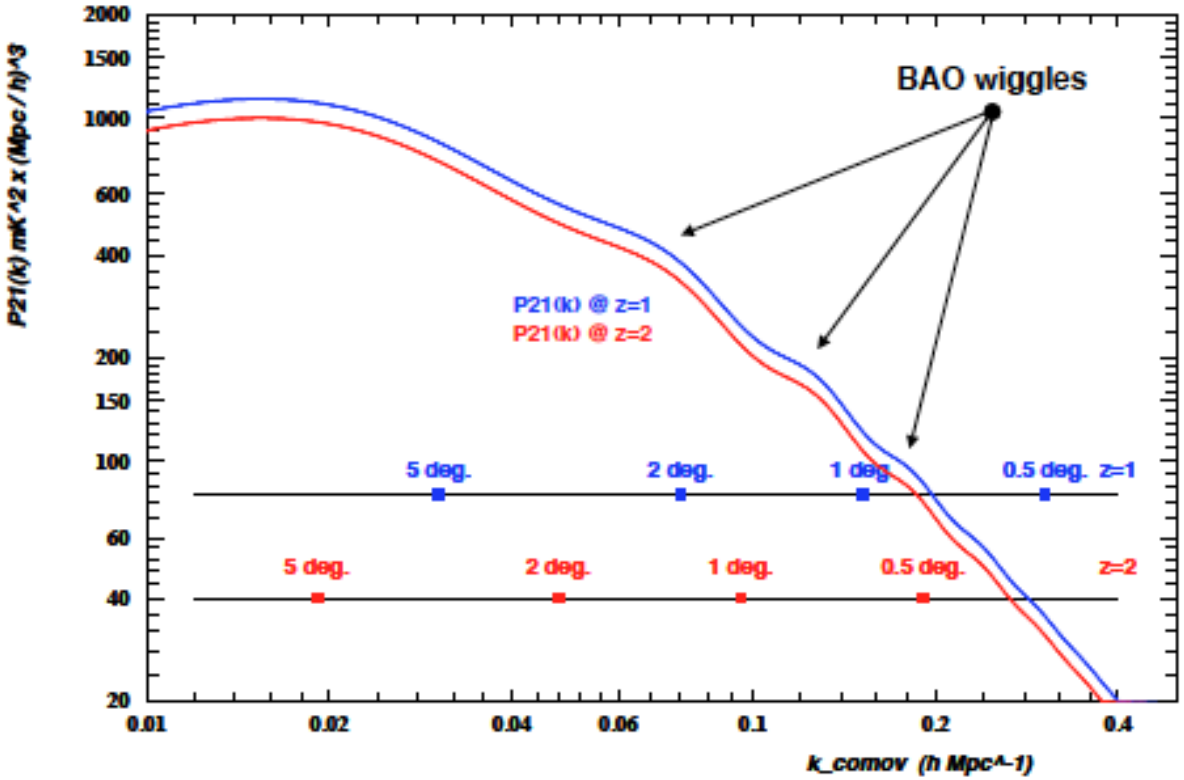


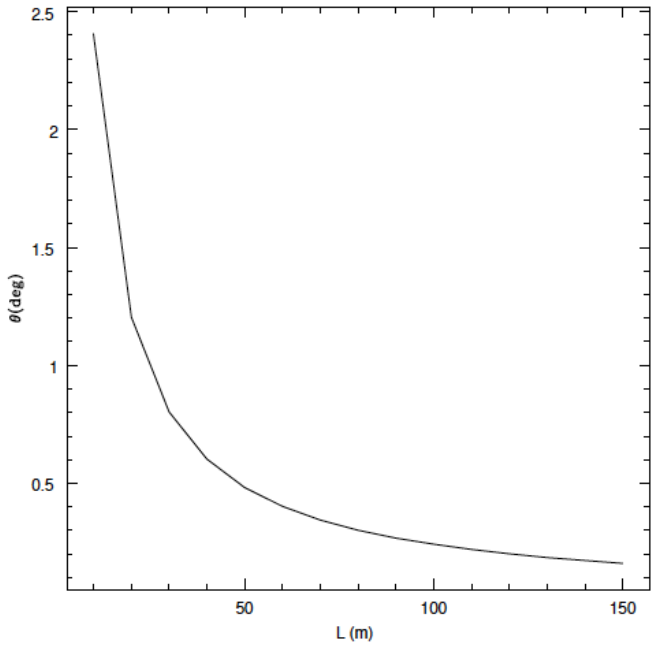
Image of Milky Way HI (Bandura et al.)

Design Considerisions

- Dedicated experiment, moderate cost
- Drift Scan (less cost, more stable)
- 0<z<3, first probably z=1 (sensitive to dark energy, avoids cell phone band at 850-950 MHz)

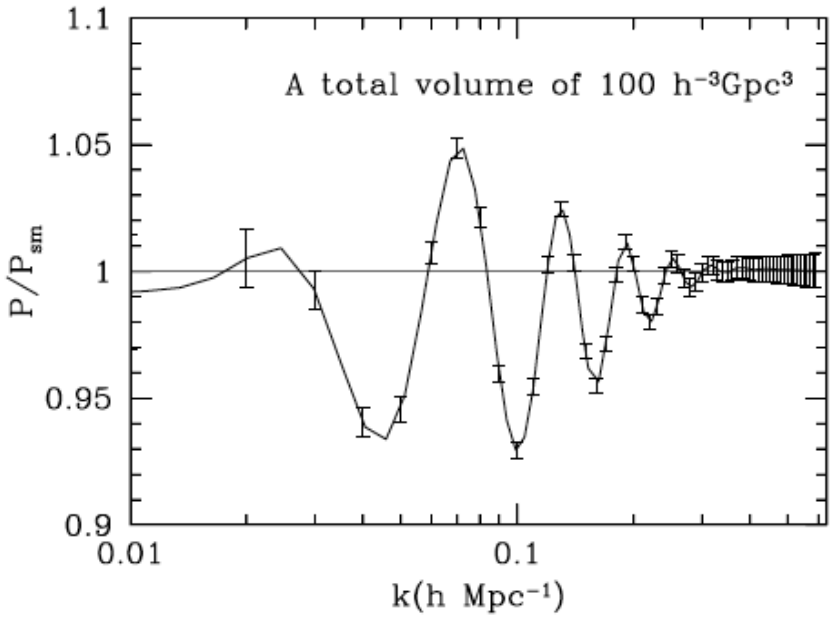
Angular Resolution



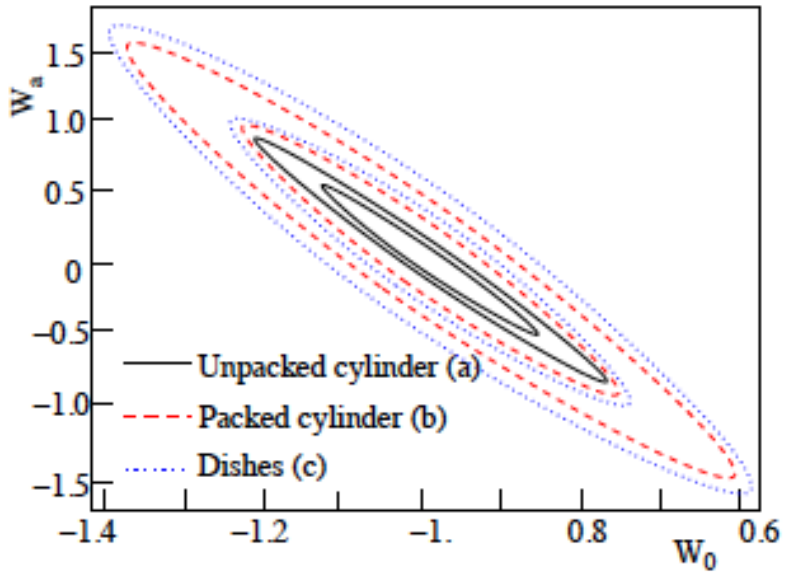


Ansari et al., 1108.1474

Experimental Design Study



H. Seo et al. 2009



R. Ansari et al. (2008)

Tianlai pathfinder experiment

- A small pathfinder experiment to check the basic principles and designs, find out potential problems
- 3x15x40m cylinders, 96 dual polarization receiver units
- 16x6m dish, steerable, possibly with tracks
- pathfinder: construction+ commission 2014-2015
- Cost: $1.5M from MOST + site construction (NAOC)
- If successful: expand to 120mx120m, 1000~ 3000 units

Forecast on Dark energy parameters

$$F_{\alpha\beta} = \sum_k \left[\frac{\partial P_{\rm obs}(k)}{\partial \alpha} \frac{\partial P_{\rm obs}(k)}{\partial \beta} \right] / \left[\Delta P_{\rm obs}(k) \right]^2$$

$$\frac{1}{\sqrt{N_c}} \left[P_{\rm obs}(k) + N(k) \right]$$

$$P_{\rm obs}(k_{\rm ref\perp}, k_{\rm ref\parallel}) = \frac{D_A(z)^2_{\rm ref} H(z)}{D_A(z)^2 H_{\rm ref}(z)} \left(1 + \beta \frac{k_\parallel^2}{k_\perp^2 + k_\parallel^2} \right)^2 \times (b_1^{\rm HI})^2 G(z)^2 P_{\rm m0}(k) + P_{\rm shot}$$

$$b_i^{\rm HI}(z) = \frac{\int_{M_{\rm min}}^{M_{\rm max}} dM\, n(M,z)\, M_{\rm HI}(M)\, b_i(M,z)}{\rho_{\rm HI}}$$

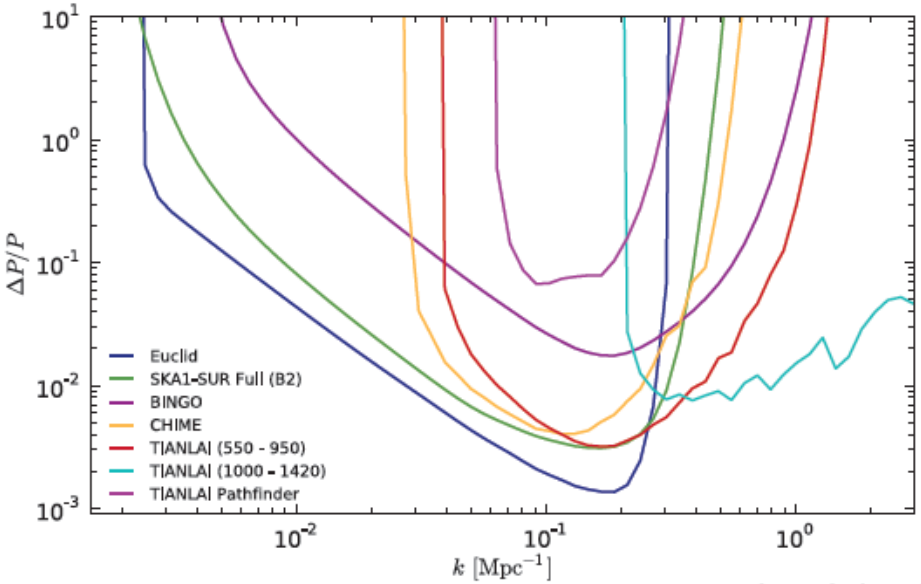
Tianlai...

Slide from M. Santos

- Assumptions – Pathfinder:

Number of cylinders	3
Cylinder width [m]	15
Feeds per cylinder	32 (dual-pol)
Feed spacing [m]	0.5
Tsys [K]	50
Bandwidth [MHz]	700 - 800
Channel width [MHz]	6.25
Number of Channels	16
Telescope latitude	45 degree

- Assumptions – Full:
  - 8 x 15m x120m cylinders,
  - ~ 256 feeds per cylinder dual polarisation – spacing ~ 42cm
  - T_inst=50K
  - 450MHz–1420MHz (400 MHz bandwidth)
  - survey area 10,000 deg^2



Credit: Phil Bull

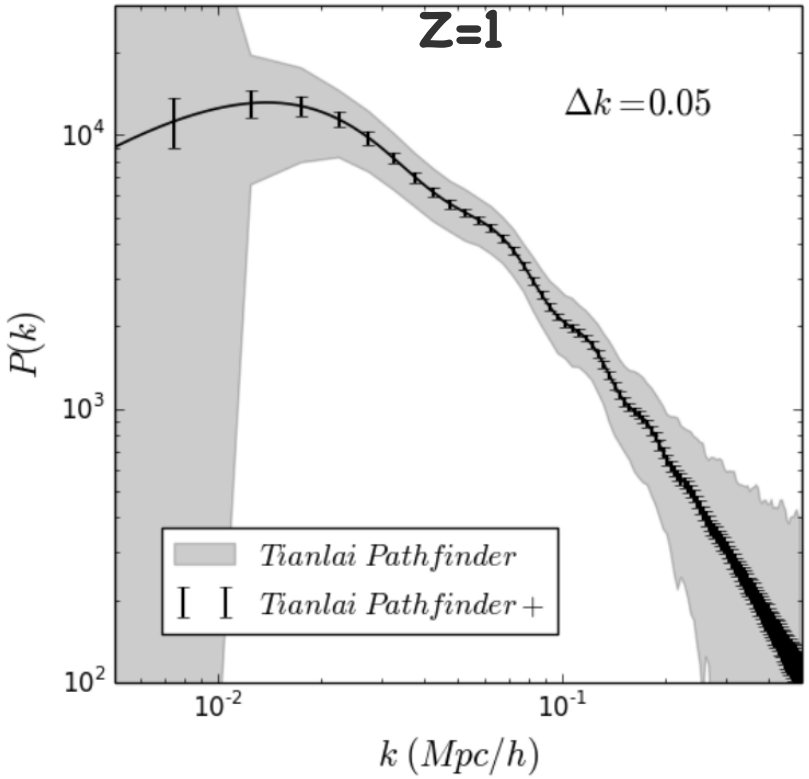
Power spectrum constraints

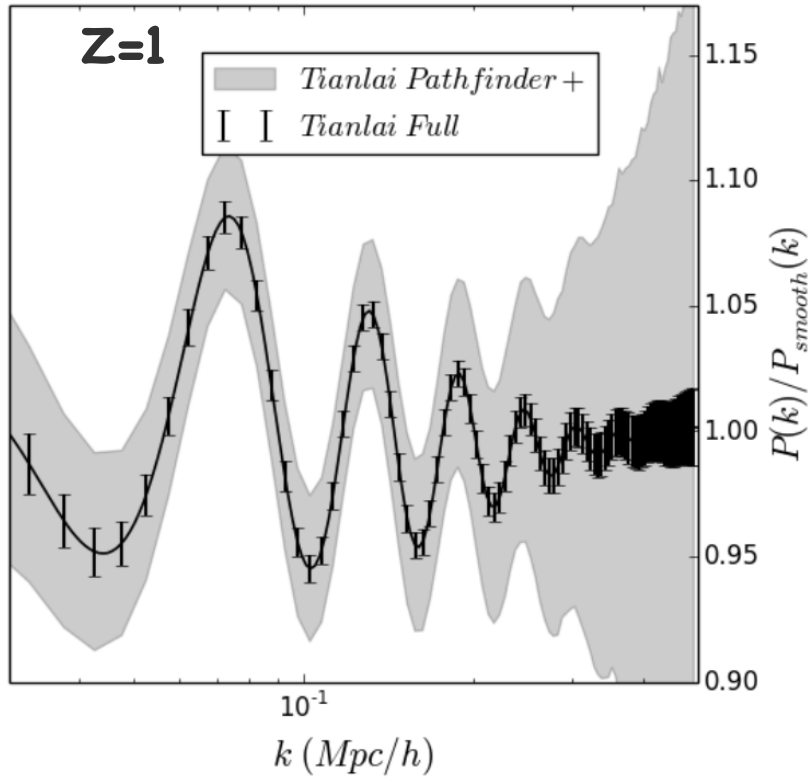
Forecast on Dark energy parameters

Y. Xu, X. Wang, XC, in preparation

Table 1: The experiment parameters for Tianlai.

	No. of cylinders	cylinder width	cylinder length	dual pol. units/cylinder	bandwidth
Pathfinder	3	15m	40m	32	700-800MHz
Pathfinder+	3	15m	40m	72	700-800MHz
Full scale	8	15m	120m	256	400-1420 MHz





Forecast on Dark energy parameters

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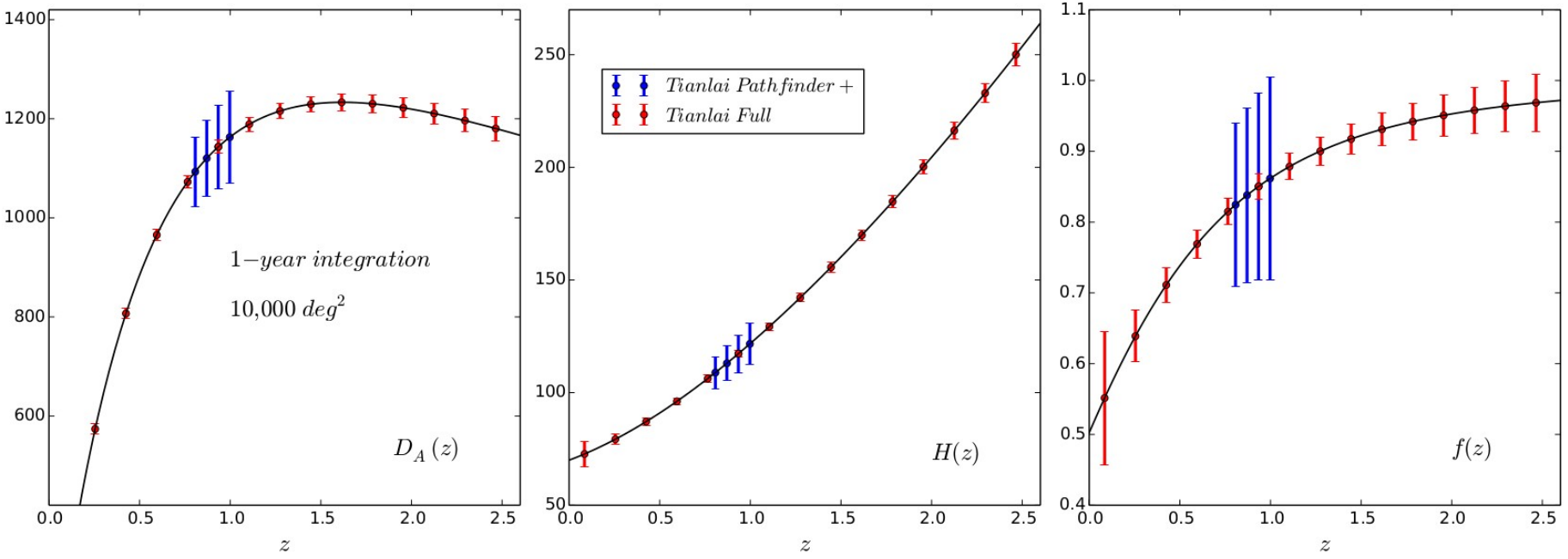
$$f(z) = d\ln D_{\rm A}/d\ln a$$



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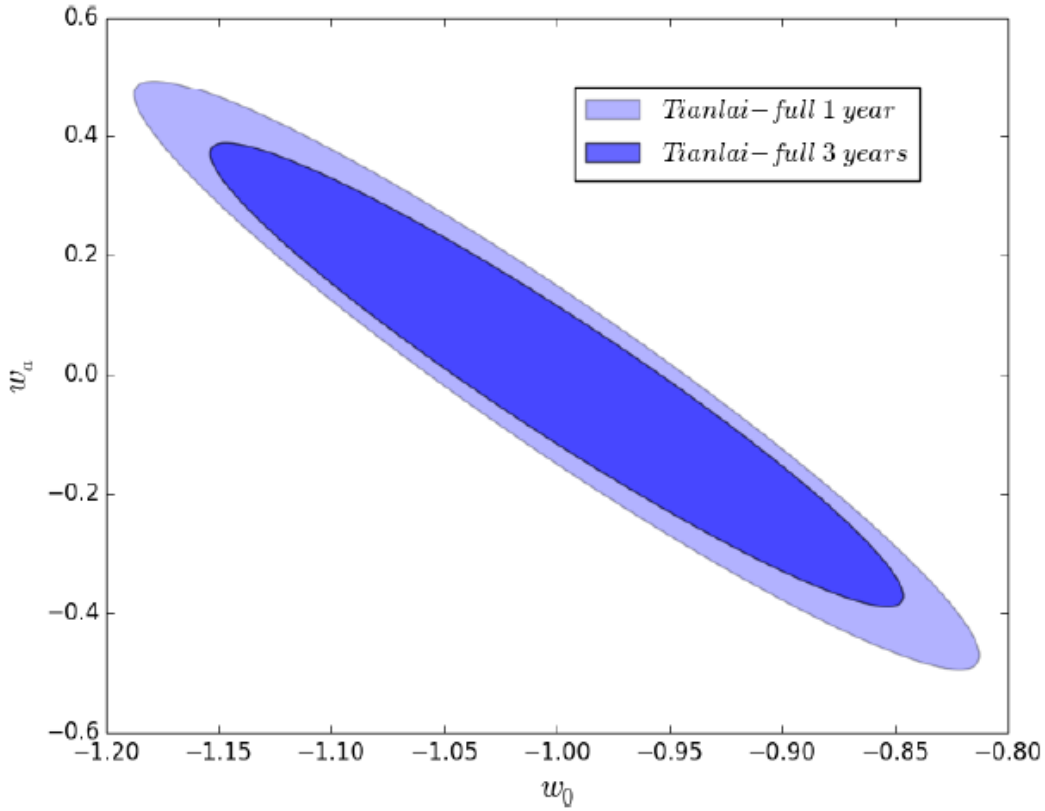

Forecast on Non-gaussianity

WMAP-9-year data(Giannantonia et al.2013):

$$f_{NL}^{local} = 5 \pm 21 \qquad 1\sigma$$

Planck:

$$f_{\rm NL}^{\rm local} = 2.7 \pm 5.8,\ f_{\rm NL}^{\rm equil} = -42 \pm 75,$$

$$f_{\rm NL}^{\rm ortho} = -25 \pm 39 \qquad 1\sigma$$

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Full scale	8	15m	120m	256	400-1420 MHz

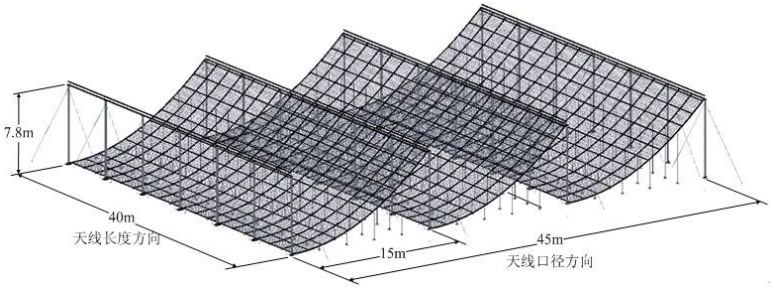
Table 2. The predicted $1-\sigma$ errors of $f_{\rm NL}$ using HI power spectrum measured by Tianlai

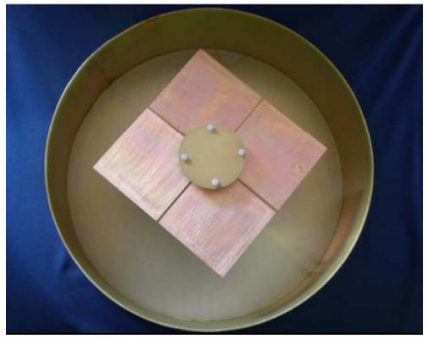
$N_{\rm feed}$ per cylinder	Pathfinder 32	Pathfinder+ 72	Full scale 256
$\sigma^{\rm local}_{\rm f_{NL}}$	1180	173	13.0

Table 3. The marginalized $1-\sigma$ errors of $f_{\rm NL}$ using HI bispectrum measured by Tianlai

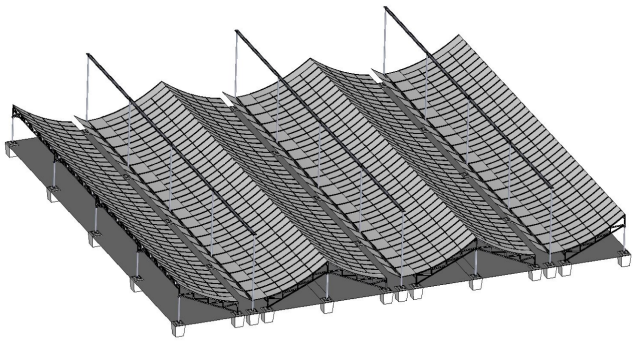
$N_{\rm feed}$ per cylinder	Pathfinder 32	Pathfinder+ 72	Full scale 256
$\sigma^{\rm local}_{\rm f_{NL}}$	42504	2776	21.3
$\sigma^{\rm equil}_{\rm f_{NL}}$	48022	3284	150

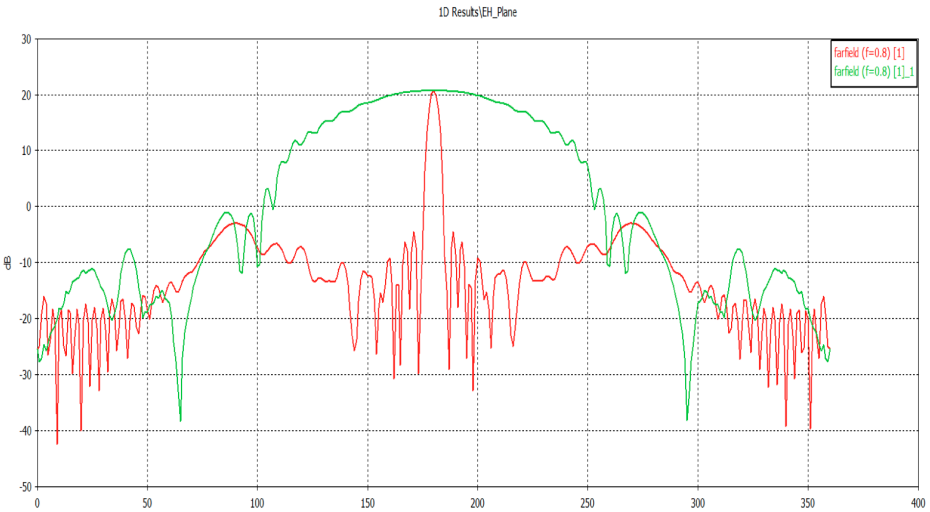
Antenna and Feeds





made in CETC-54





T. Liu, CST simulation

Cylinder Structure

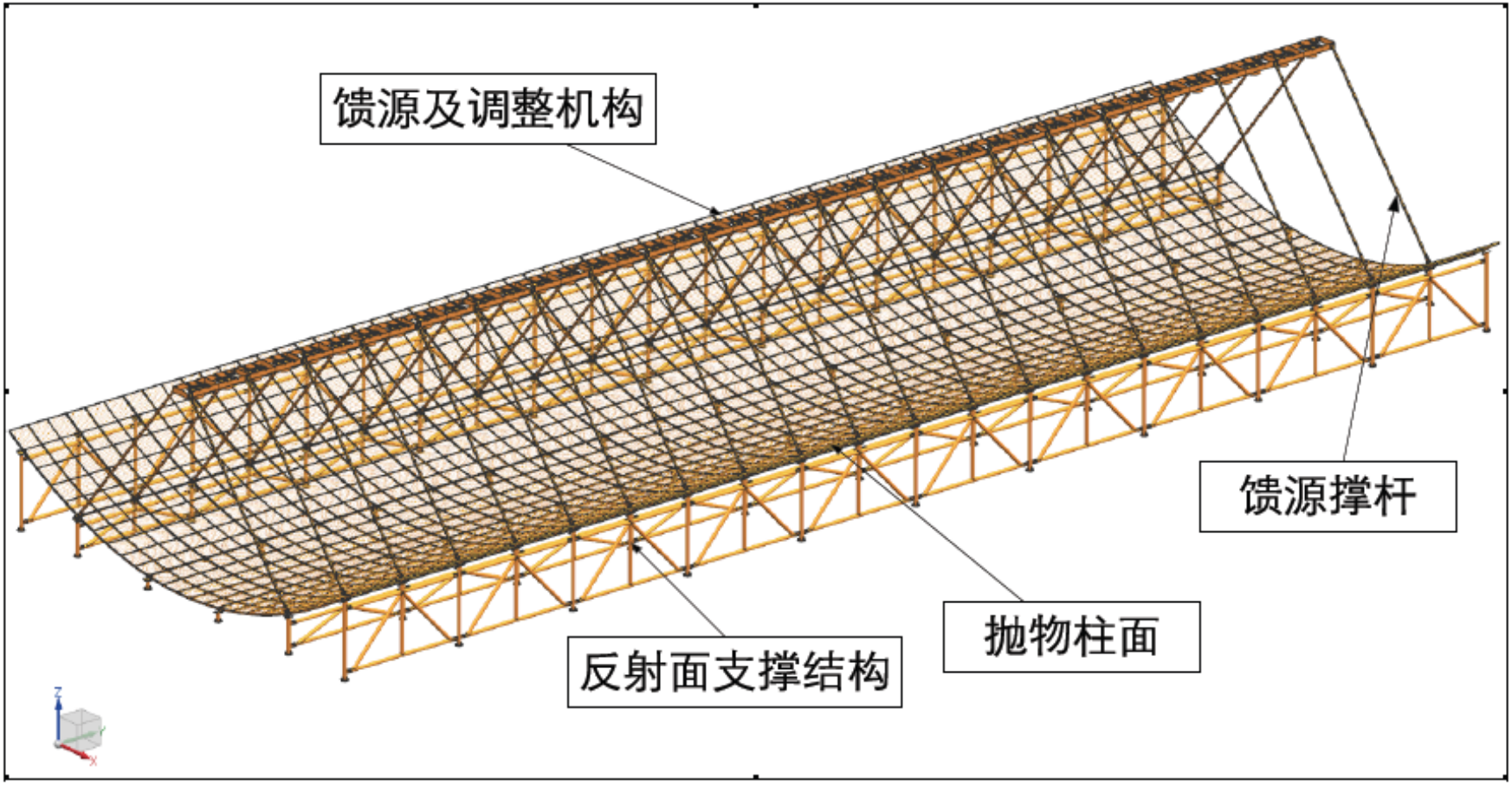
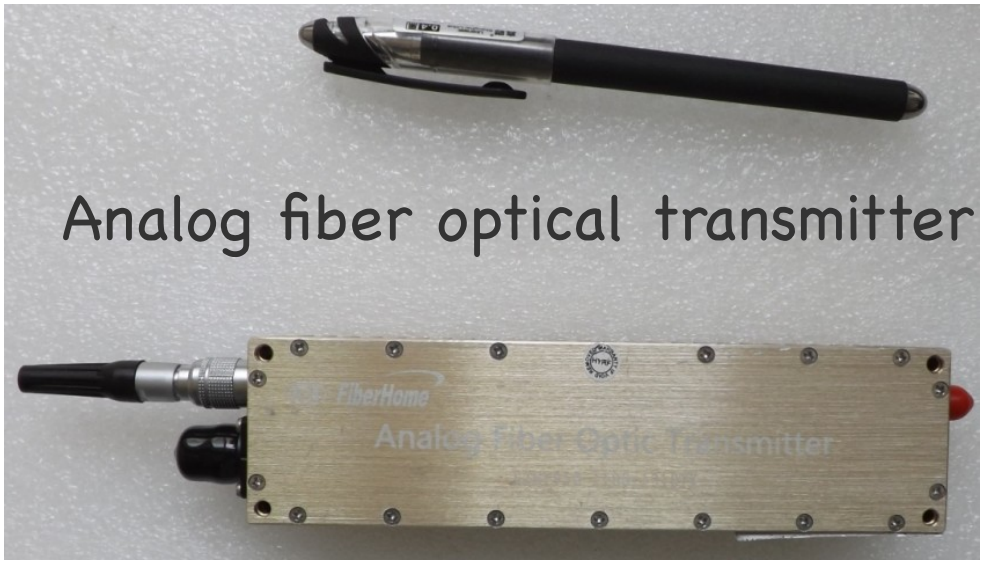


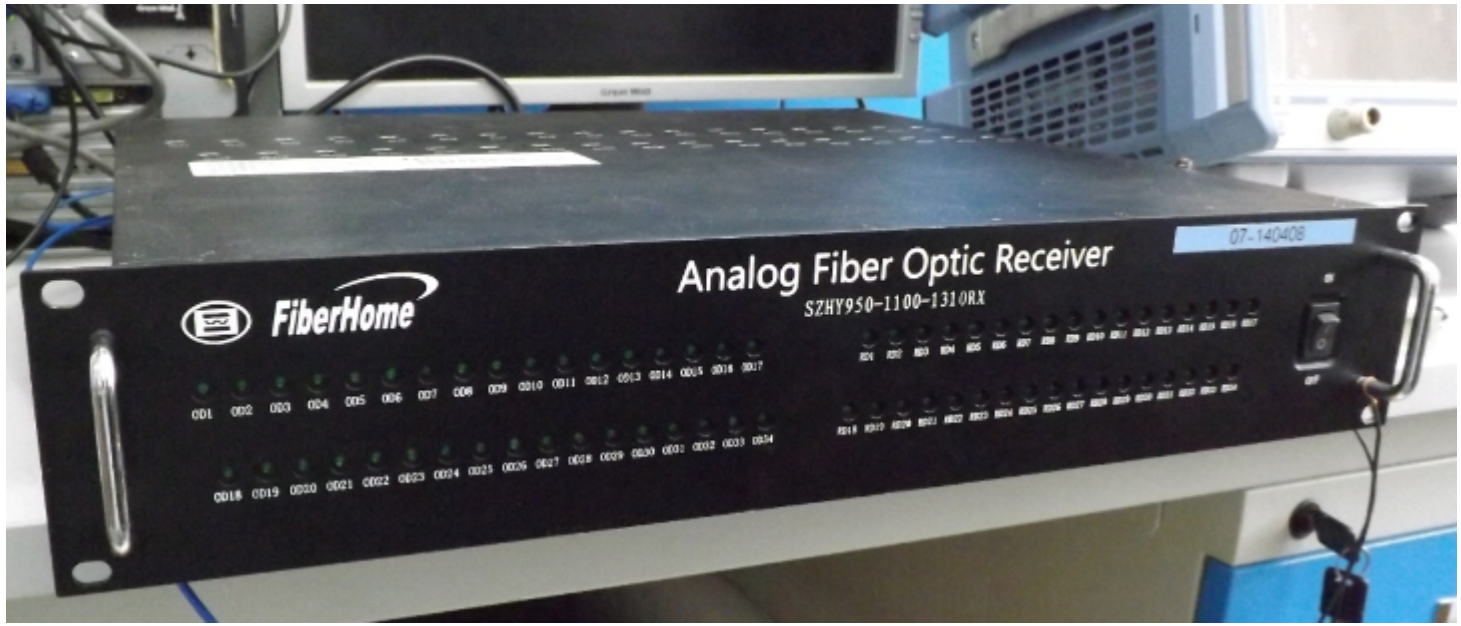
图 2　15m×40m 抛物柱面天线组成

6m dish

Frequency:0.4-1.5Ghz
NF=0.6 T_n=43K @750Mhz
Gain>53dB
Coaxial cable power supply



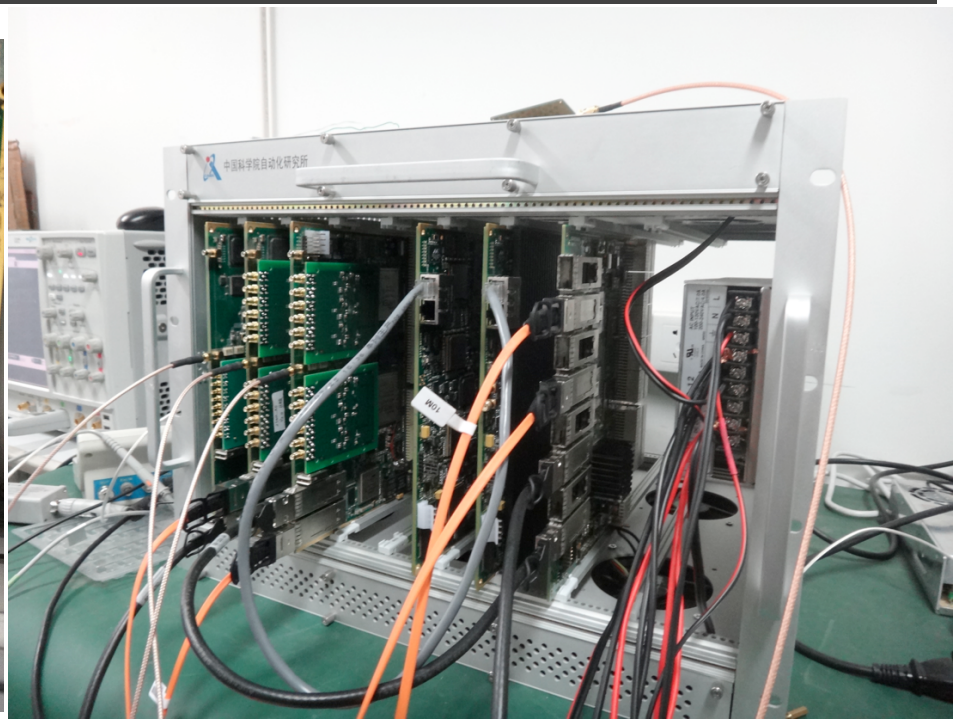
Frequency:0.4-1.5Ghz
DFB Lazer, no thermostat syster
Gain>18dB
P_n=-130dBm
DC28V power
Power of light > 2.0dBm


FiberHome
Analog Fiber Optic Receiver
SZHY950-1100-1310RX
07-140408


RF12 RF11 RF10 RF9 RF8 RF7 RF6 RF5 RF4 RF3 RF2 RF1
RF22 RF21 RF20 RF19 RF18 RF17 RF16 RF15 RF14 RF13
RF34 RF33 RF32 RF31 RF30 RF29 RF28 RF27 RF26 RF25 RF24 RF23


L频段下变频器
3
07-140432
07-140436
07-140440
07-140433
07-140437
07-140441
07-140434
07-140438
07-140435
07-140439
L频段下变频器
1
07-140410
07-140414
07-140418
07-140411
07-140415
07-140419
07-140412
07-140416
07-140420
07-140413
07-140417
AC-220V
CETC 54
CETC 54

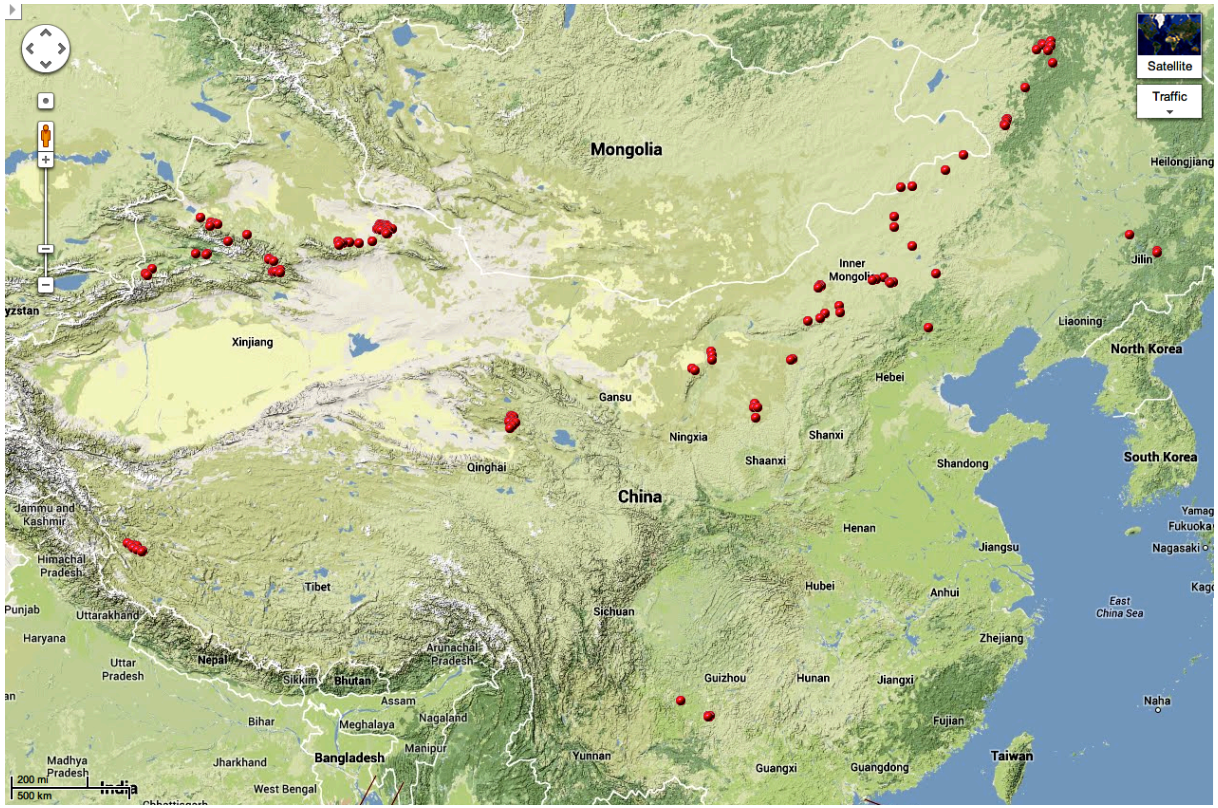
Digital Components



Developed by the Institute of Automation, we are also experimenting with GPUs for larger array

Site Surveys in China

- Low RFI (low population density, shielded by mountains)
- wide open terrain
- convenience in logistics, electricity,communication
- We checked for about 100 potential sites (found on Google Earth) near existing astronomical research facilities

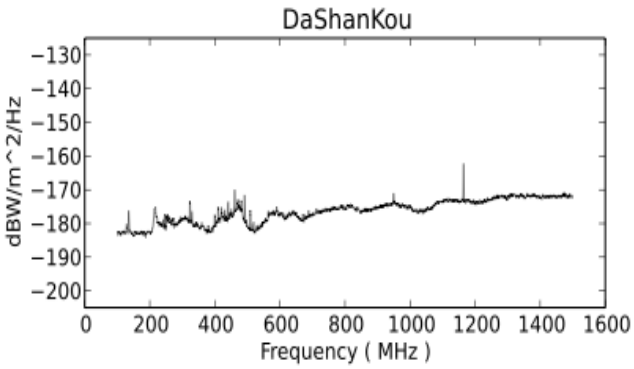


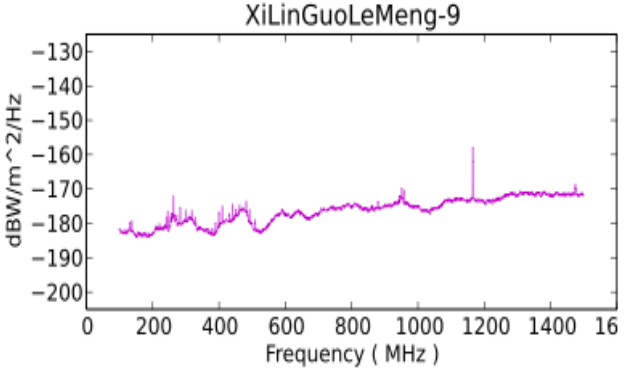

A site in Baiqi, Inner Mongolia


A site in Pingtang, Guizhou, SW China


A site in Jiaohe, Jilin, NE China


A site in Ali, Tibet, W. China


DaShanKou
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
0
200
400
600
800
1000
1200
1400
1600
Frequency (MHz)


XiLinGuoLeMeng-9
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
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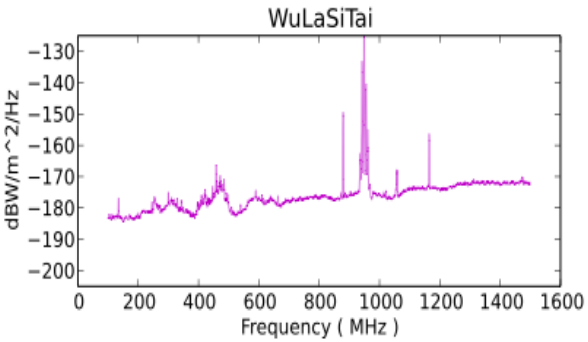
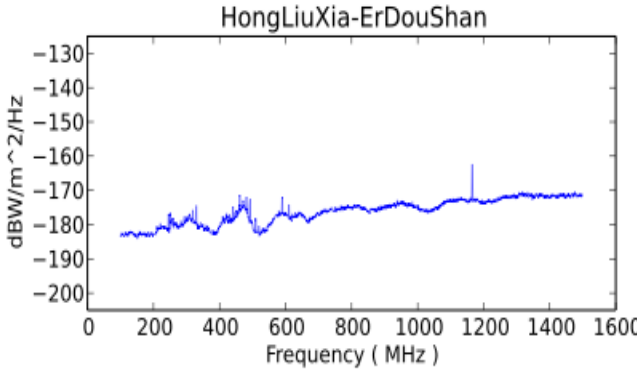
400
600
800
1000
1200
1400
Frequency (MHz)


WuLaSiTai
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
0
200
400
600
800
1000
1200
1400
1600
Frequency (MHz)


HongLiuXia-ErDouShan
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
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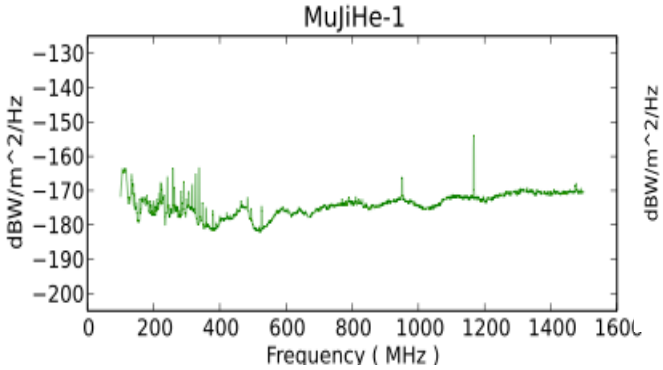
400
600
800
1000
1200
1400
Frequency (MHz)


MuJiHe-1
dBW/m^2/Hz
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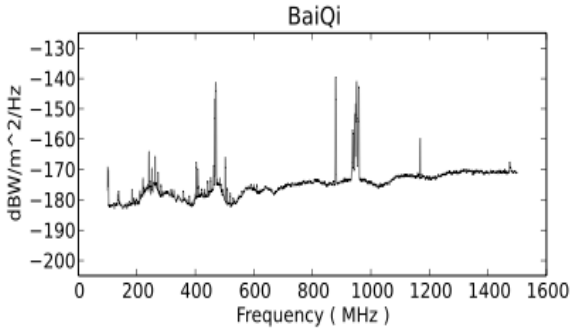
−140
−150
−160
−170
−180
−190
−200
0
200
400
600
800
1000
1200
1400
Frequency (MHz)


BaiQi
dBW/m^2/Hz
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−170
−180
−190
−200
0
200
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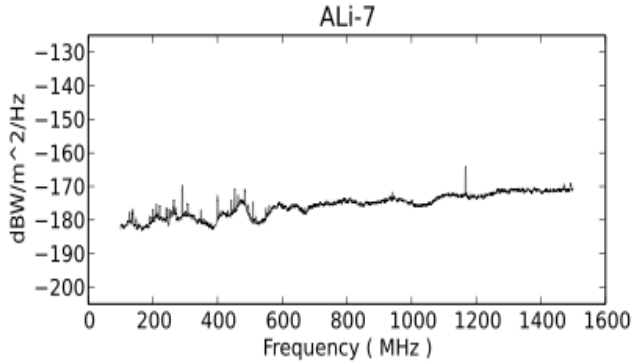
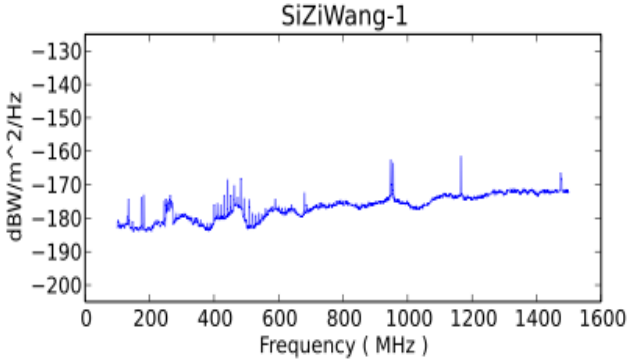
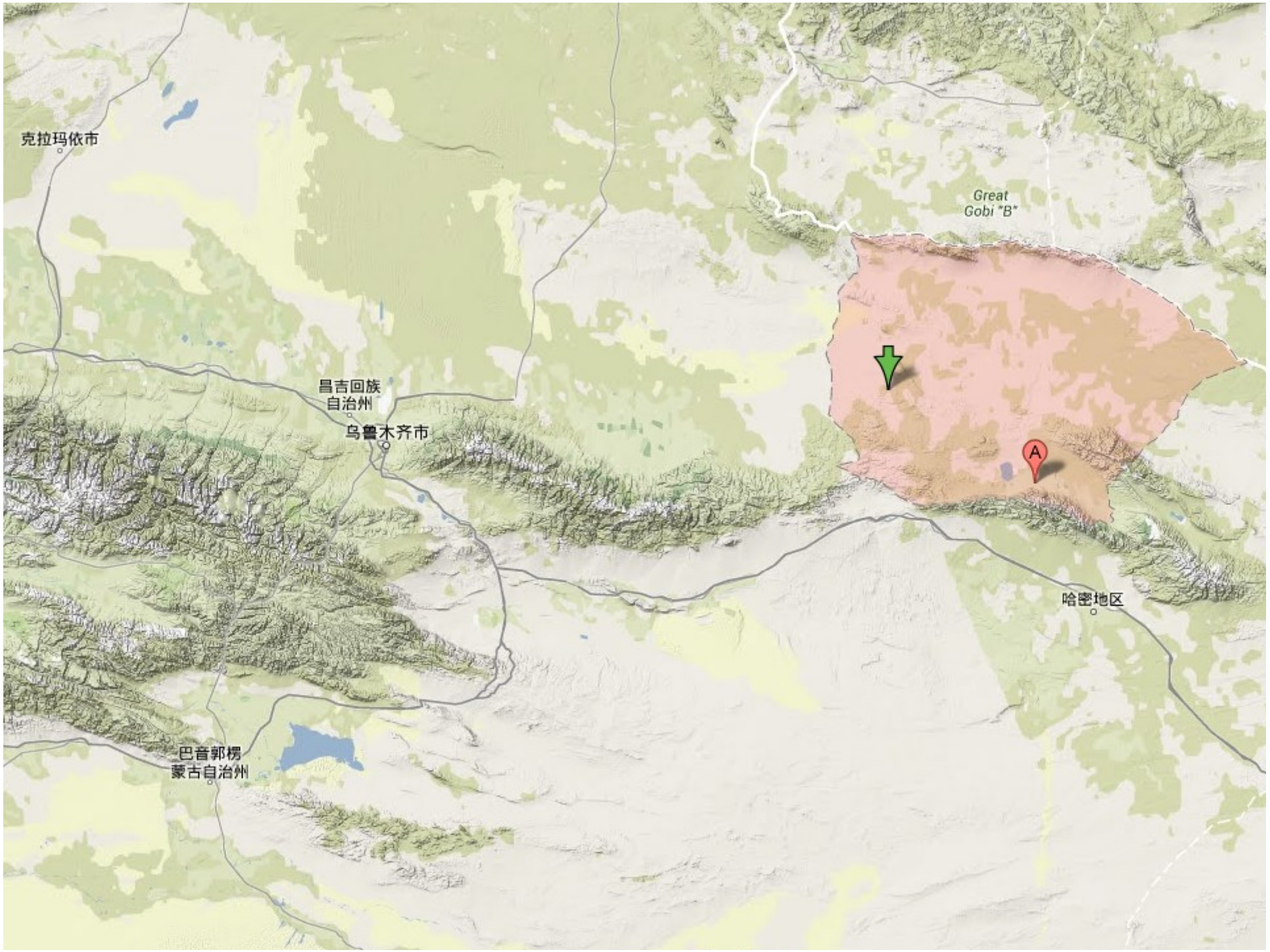
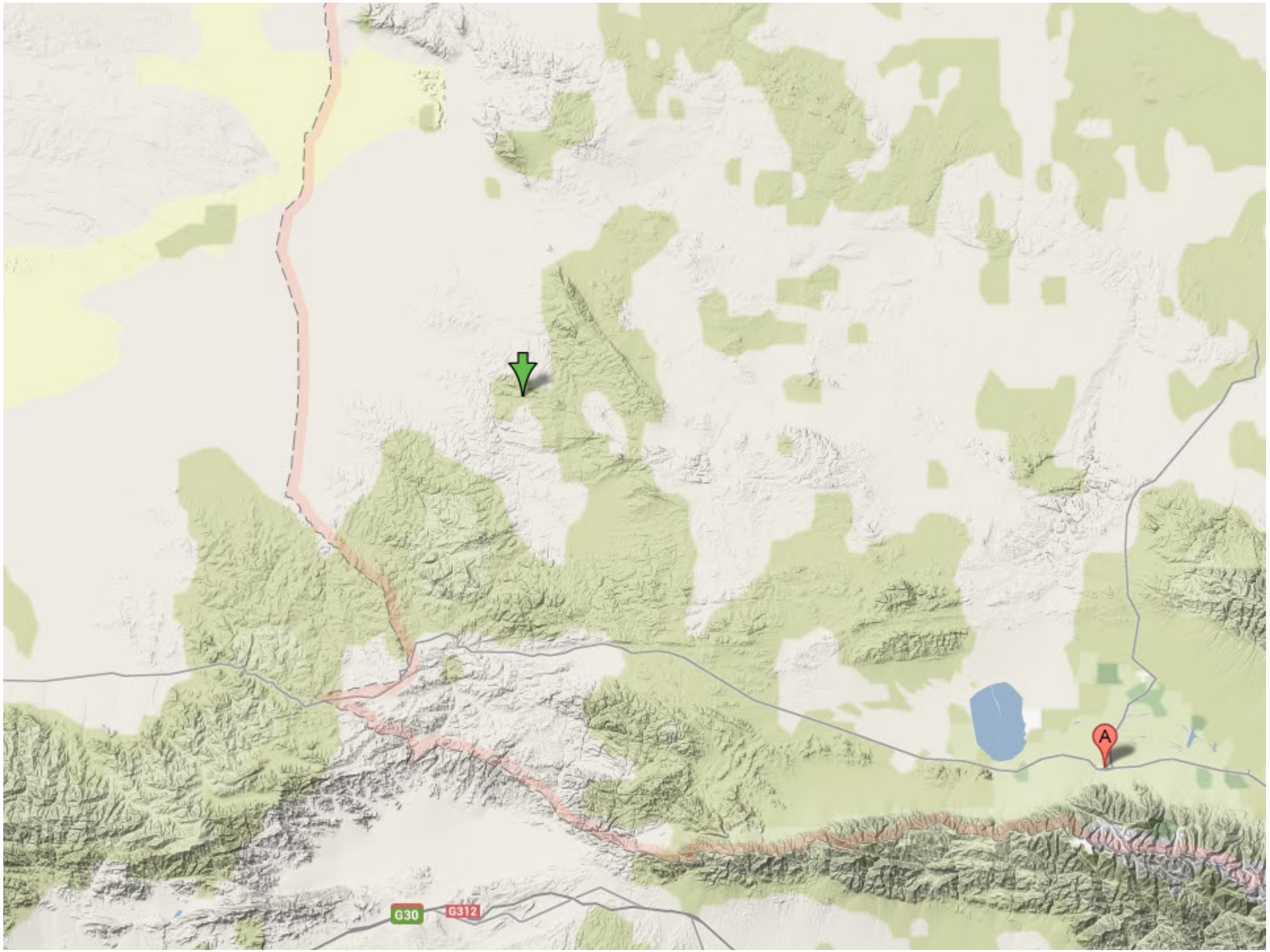
600
800
1000
1200
1400
1600
Frequency (MHz)


ALi-7
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
0
200
400
600
800
1000
1200
1400
1600
Frequency (MHz)


SiZiWang-1
dBW/m^2/Hz
−130
−140
−150
−160
−170
−180
−190
−200
0
200
400
600
800
1000
1200
1400
1600
Frequency (MHz)

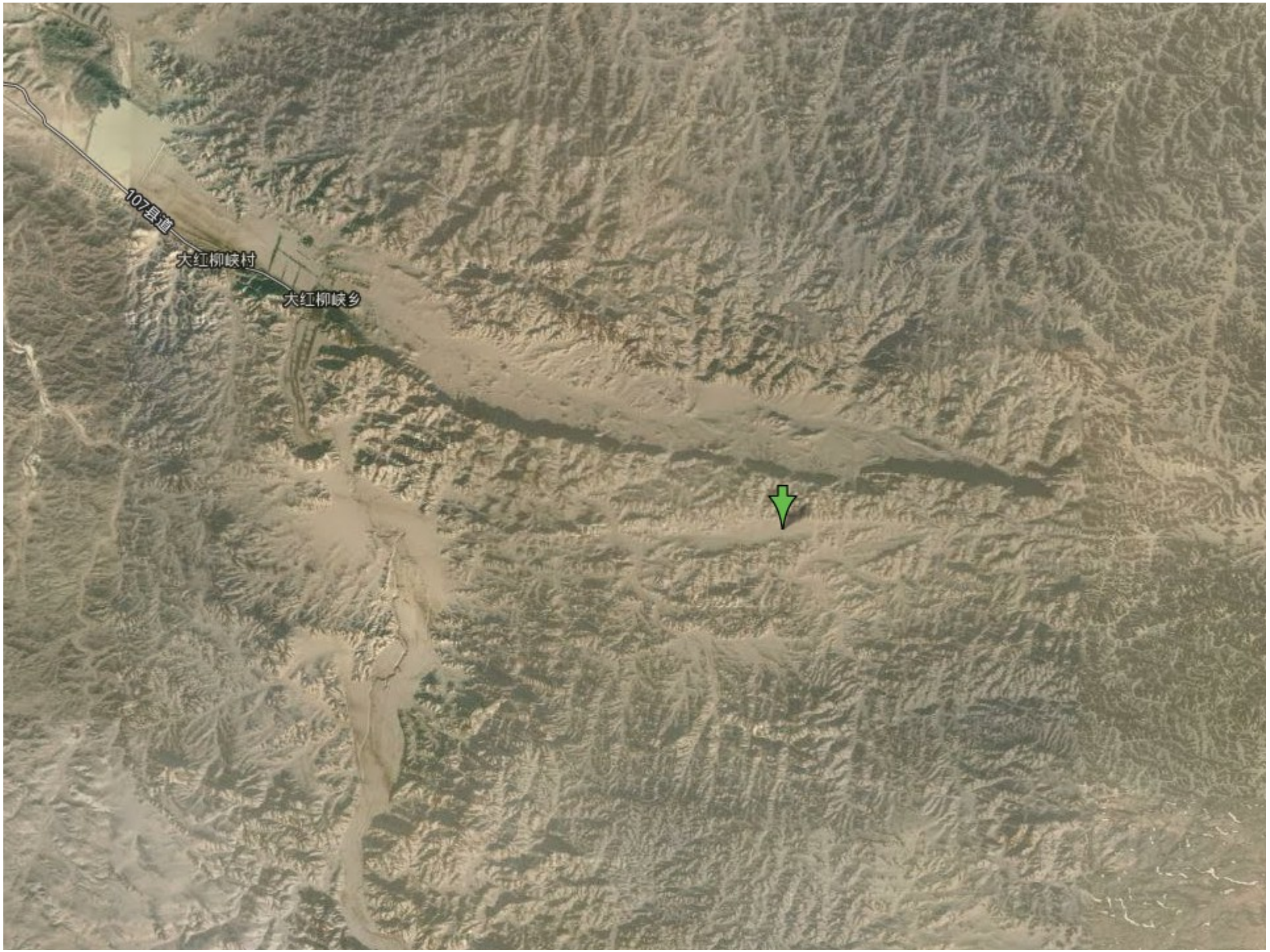

Новосибирск
Астана
Astana
Қазақстан
Улаанбаатар
Ulaanbaatar
Монгол Улс
A
Алматы
Almaty
Бишкек
Bishkek
Кыргызстан
Тошкент
Samarqand
Точикистон
北京
북한
Pyongyang
평양
서울
대한민국
Sea of Japan
札幌
日本
名古屋
東京
広島
大阪
福岡
Kabul
中国
Rawalpindi
Lahore
成都
重庆
武汉
上海
East China Sea
New Delhi
Jaipur
Lucknow
Bhutan
Karachi
Ahmedabad
India
Kolkata
বাংলাদেশ
Myanmar (Burma)
Hà Nội
广州
香港
Hong Kong
澳門
ประเทศลาว
Mumbai
Pune
Hyderabad
Yangon
ประเทศไทย
กรุงเทพมหานคร
Việt Nam
South China Sea
Maynila
Luzon
Chennai
Bangalore
Bay of Bengal
Andaman Sea
Gulf of Thailand
Thành Phố Hồ Chí Minh
Pilipinas
Kabisayaan
Palawan
Isla sang Negros
Leyte
Sulu Sea
Mindanao
Sri Lanka
地图数据 ©2014 GS(2011)6020 Basa

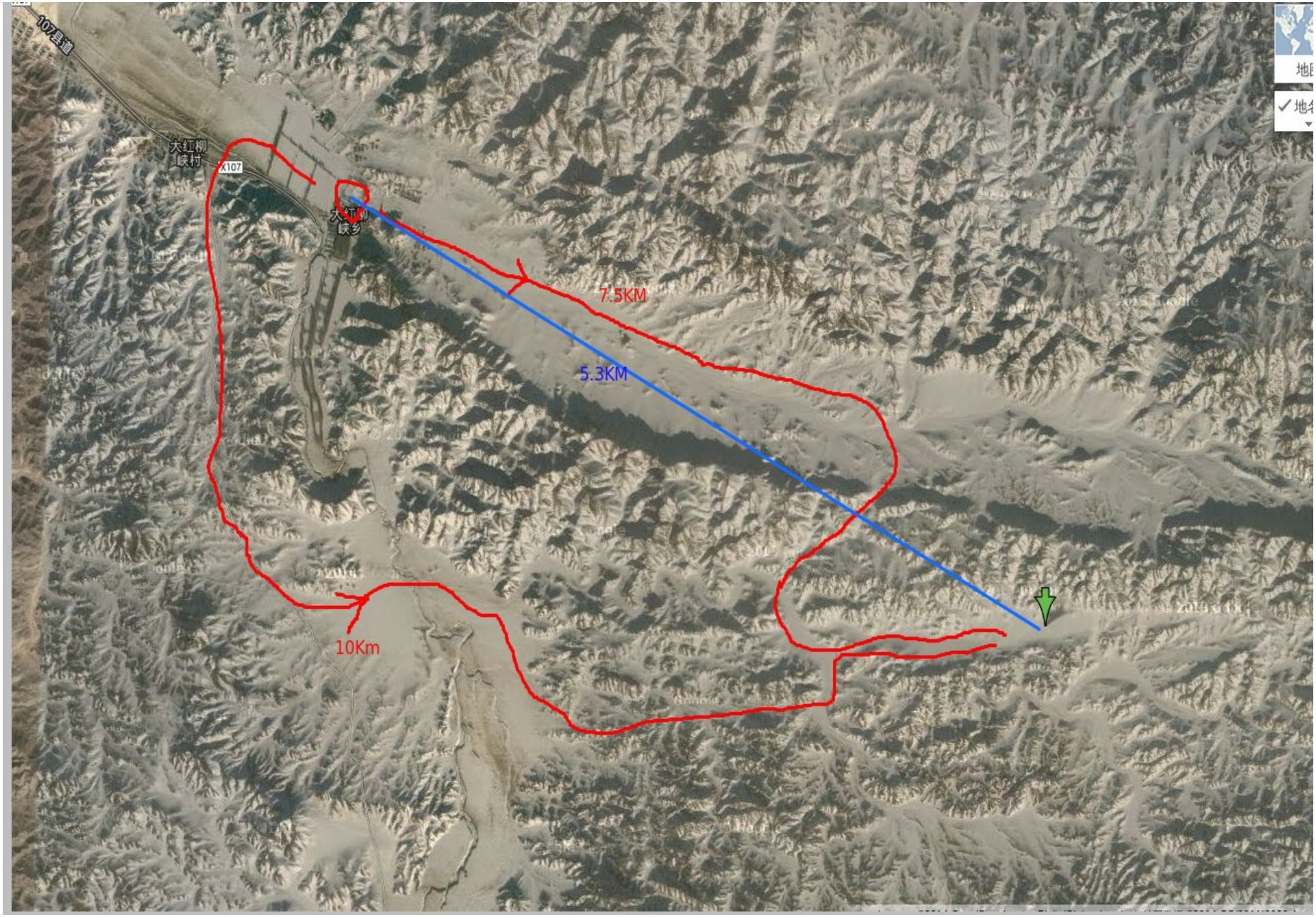

克拉玛依市
Great
Gobi "B"
昌吉回族
自治州
乌鲁木齐市
A
哈密地区
巴音郭楞
蒙古自治州

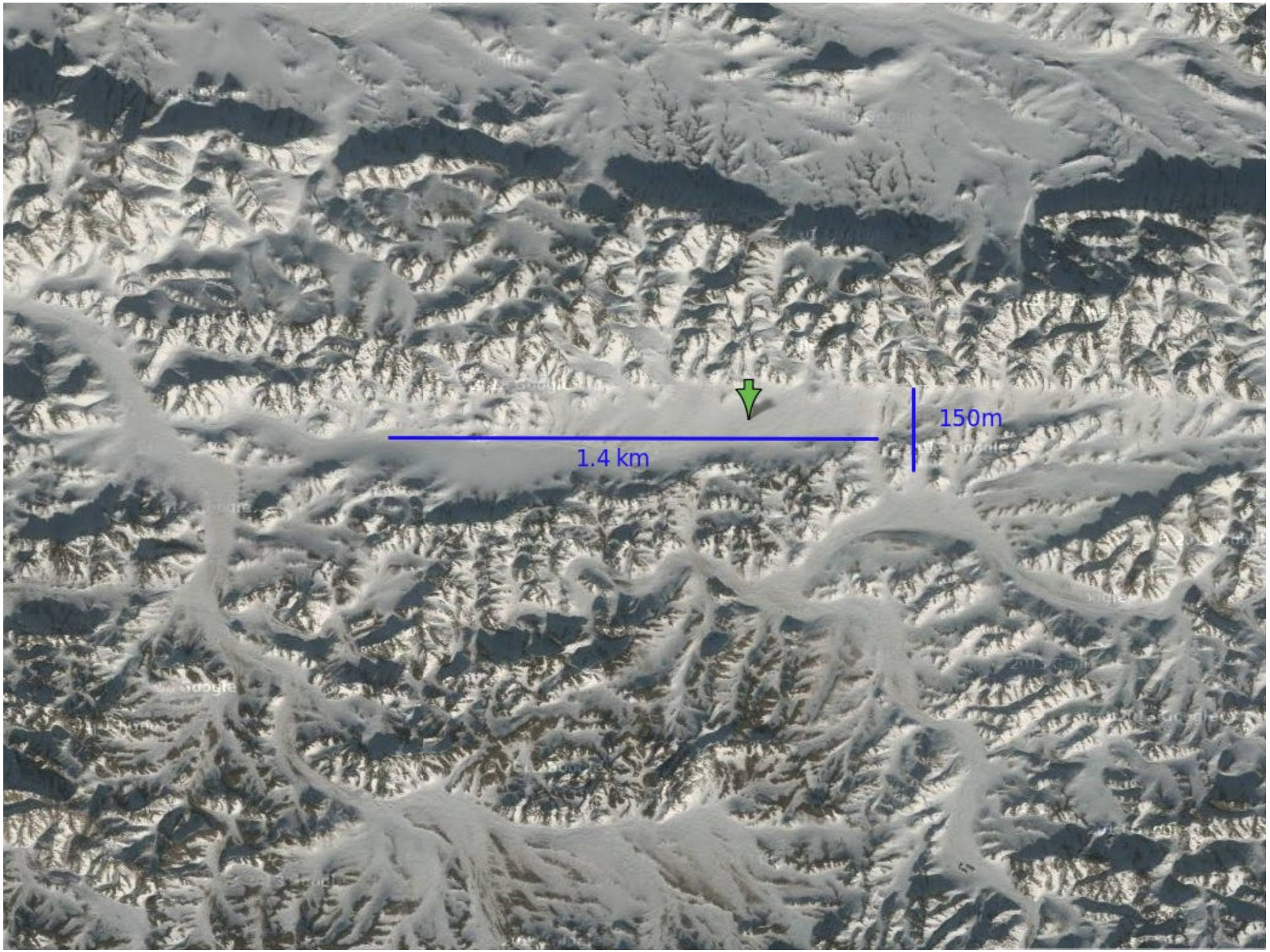

A
G30
G312


A
巴里坤哈萨克
自治县
G30
G312

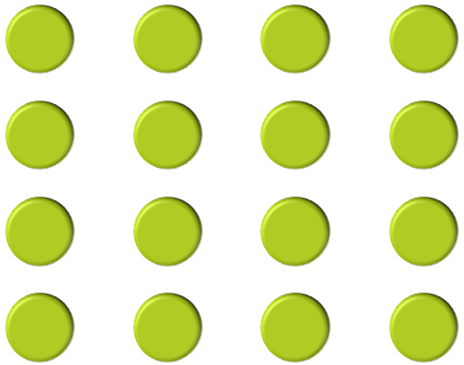
A relic beacon tower in Balikun


107县道
大红柳峡村
大红柳峡乡

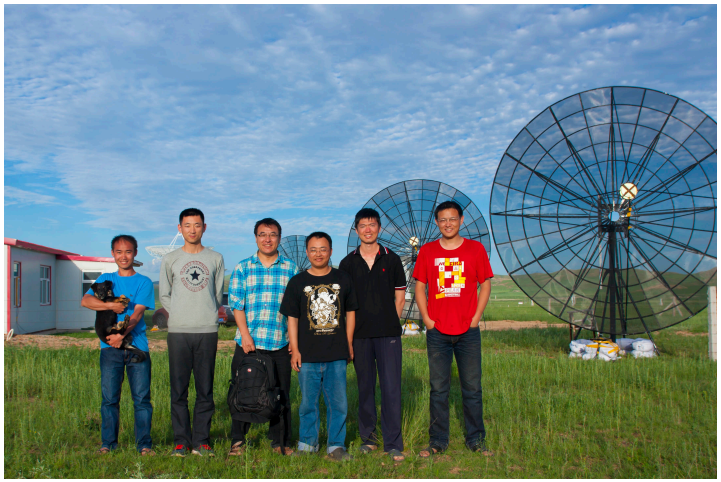

107县道
大红柳峡村
X107
大红柳峡乡
7.5KM
5.3KM
10Km


150m
1.4 km

Plan for site: Dish Array configuration?



4 unit Receiver experiment




Thanks