CHINA-US BILATERAL WORKSHOP ON ASTRONOMY, April 21-25, 2008

FAST Receivers

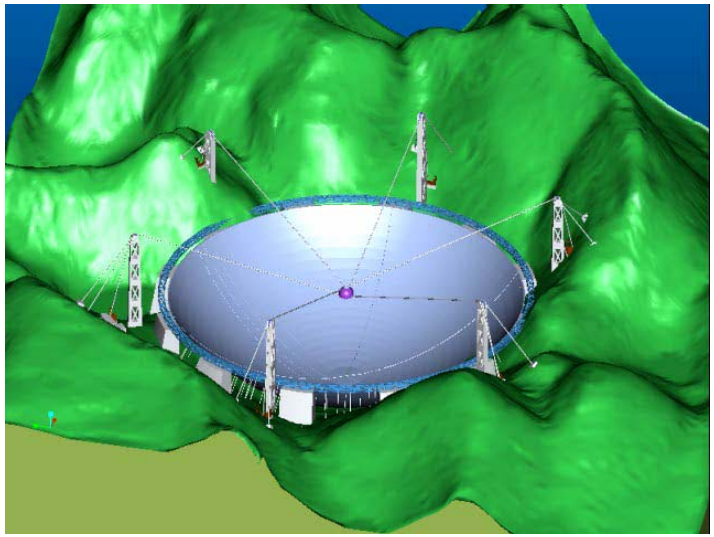
Dr. Jin Chengjin

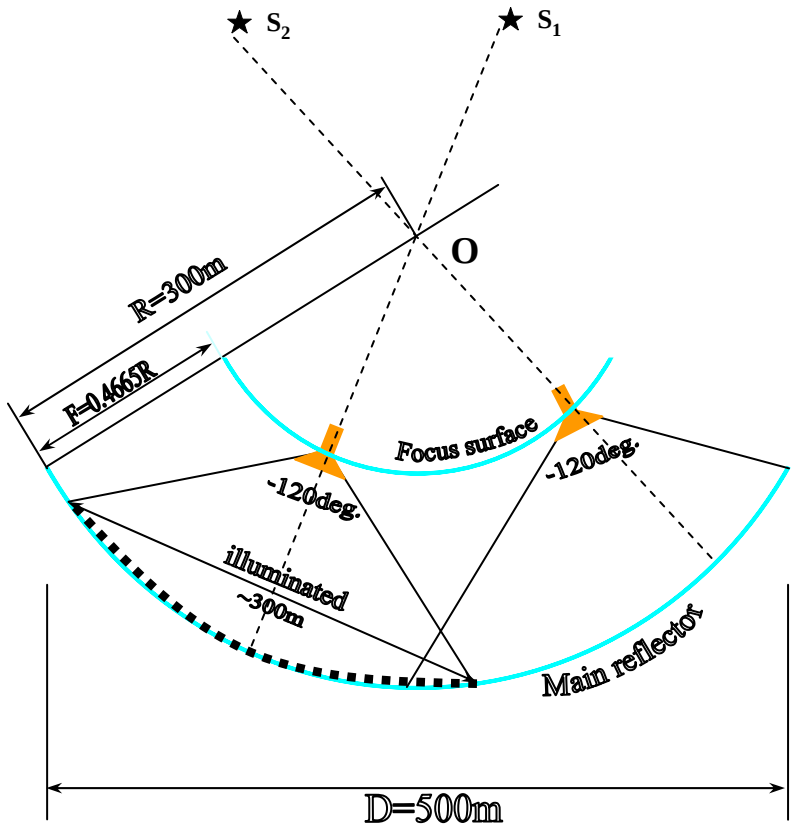
FAST, NAOC

Content

- Optics of FAST
- Layout design (NAOC-JBO)
- Future work

FAST & it's optics

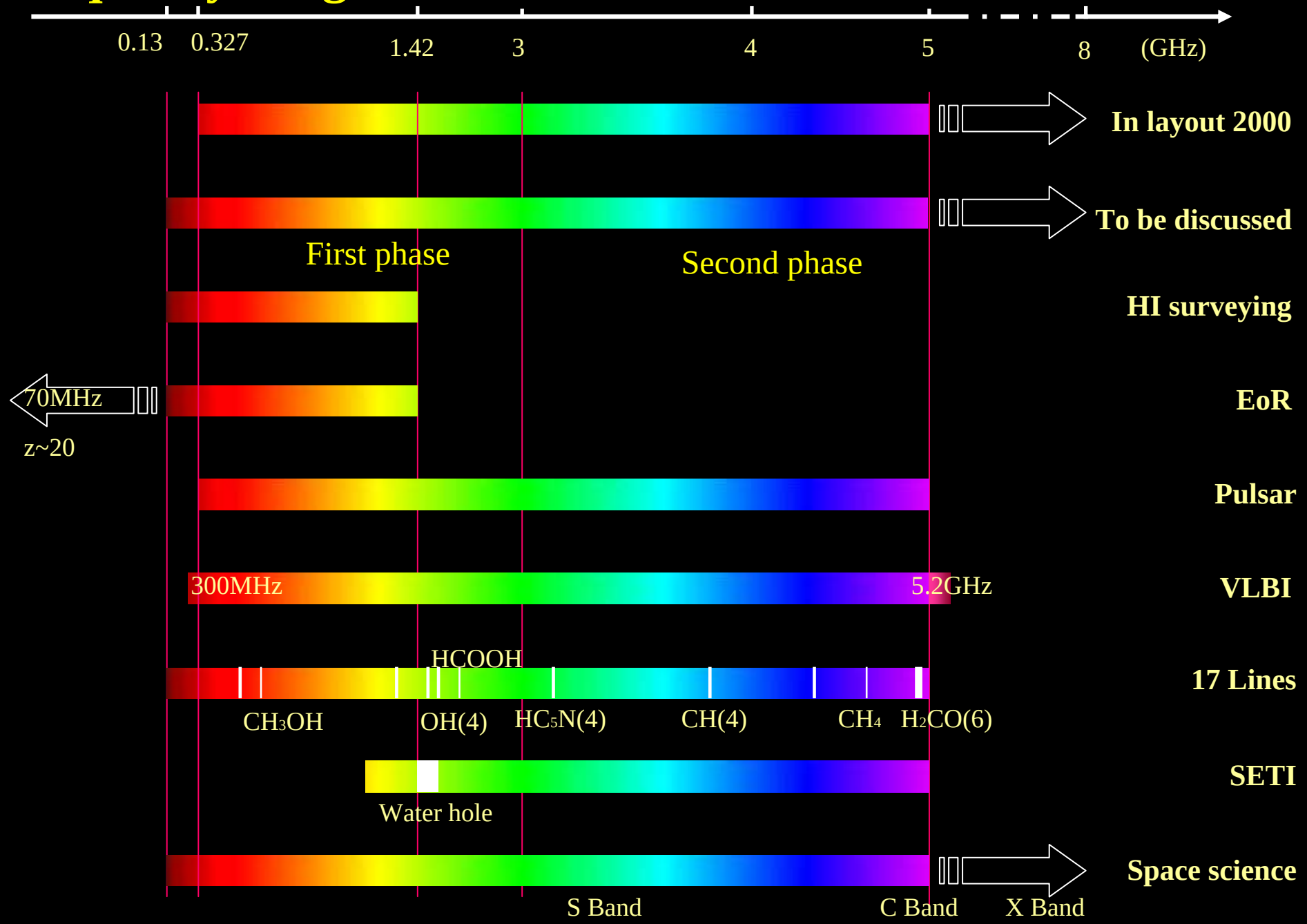


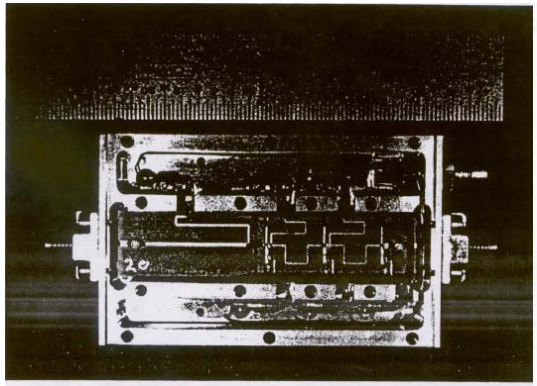


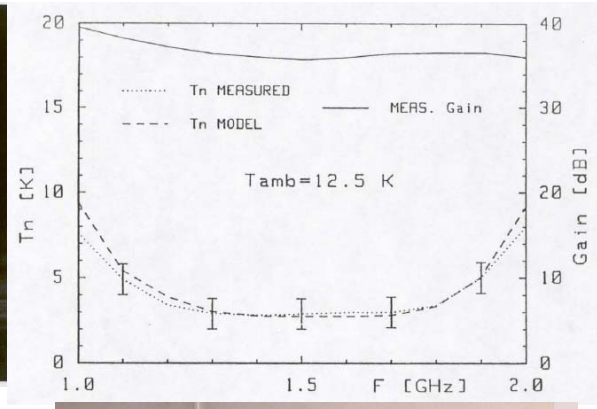
Main specs

- Spherical reflector: Radius~300m
  Aperture~500m
  Opening angle 110~120^{o}
- Illuminated aperture: 300m
- Focal ratio: 0.467
- Zenith angle: 40^{o}
- Frequency: 70-3000MHz

Frequency range





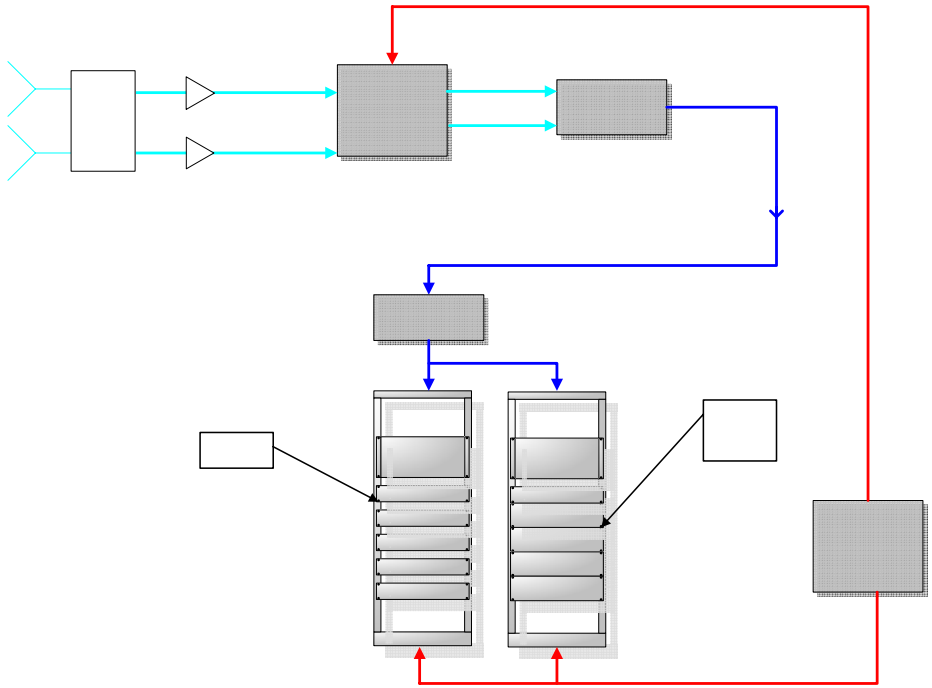

Tn MEASURED
Tn MODEL
MEAS. Gain
Tamb=12.5 K
Tn [K]
Gain [dB]
F [GHz]
0
5
10
15
20
30
40
1.0
1.5
2.0

9 sets of FAST receivers NAOC - JBO

No	Band (GHz)	Beams	Pol.	Cryo	Science
1	0.07 – 0.14	1	RCP LCP	no	High-z HI(EoR),PSR, VLBI, Lines
2	0.14 – 0.28	1	RCP LCP	no	High-z HI(EoR),PSR, VLBI, Lines
3	0.28 – 0.56	1 or multi	RCP LCP	no	High-z HI(EoR),PSR, VLBI, Lines Space weather, Low frequency DSN
4	0.56 – 1.02	1	RCP LCP	yes	High-z HI(EoR),PSR, VLBI, Lines Exo-planet science
5	0.320 – 0.334	1	RCP LCP	no	HI,PSR,VLBI
6	0.55 – 0.64	1	RCP LCP	yes	HI,PSR,VLBI
7	1.15 – 1.72	1 L wide	RCP LCP	yes	HI,PSR,VLBI,SETI,Lines
8	1.23 – 1.53	19 Lnarrow multibeam	RCP LCP	yes	HI and PSR survey, Transients
9	2.00 – 3.00	1	RCP/ LCP	yes	PTA，DSN，VLBI,SETI

0.07-0.56 GHz

- Log periodic antenna
- Room tempeture receiver
- Optical fibre for IF
- HI line, VLBI
- Tsys: sky dominated

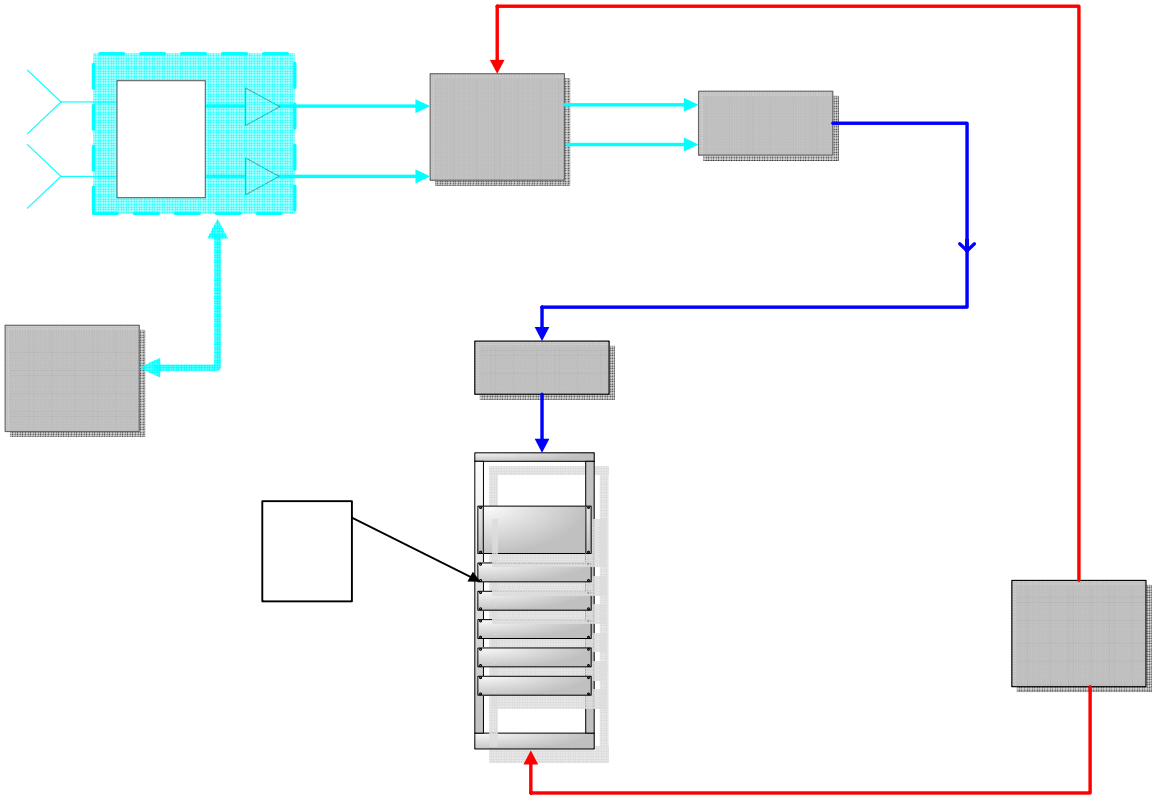


90° hybrid

0.56-1.02GHz

- Log periodic antenna
- Cooled receiver
- Optical fibre for IF
- Line, VLBI

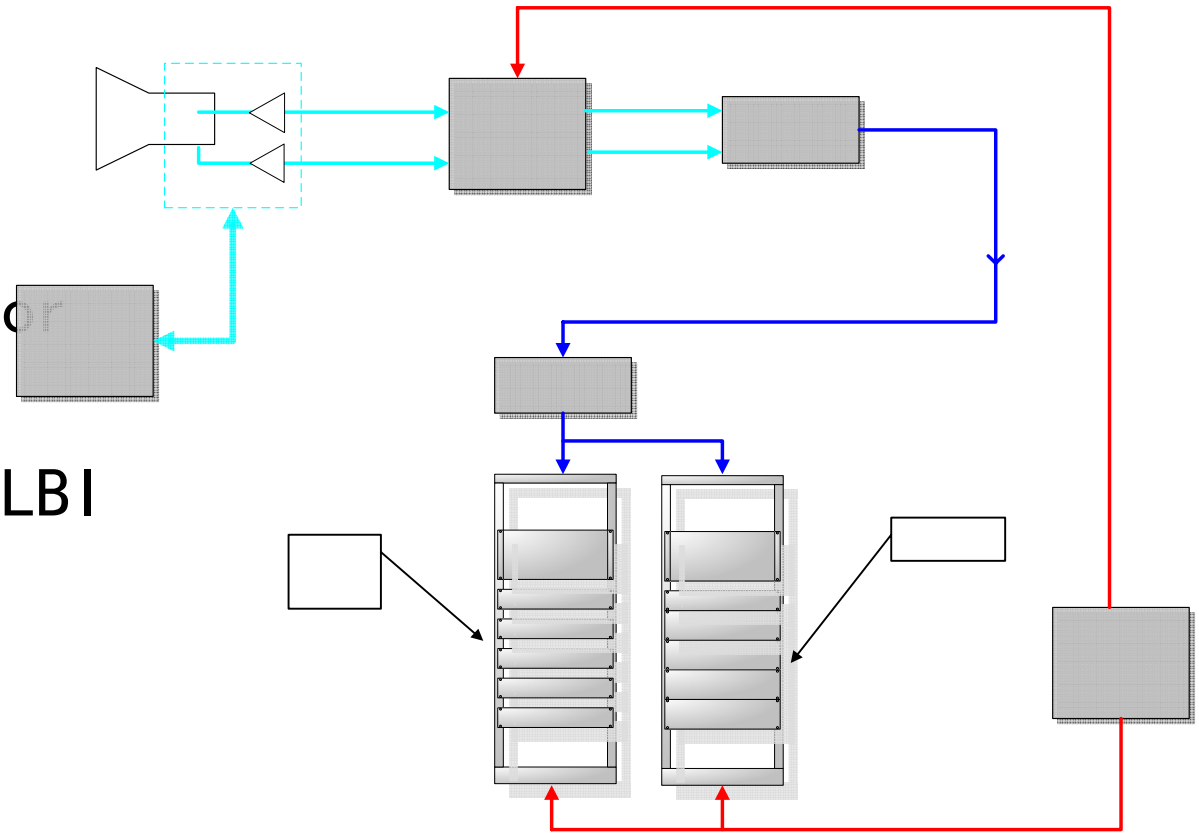
- Tsys ～60K



1.15-1.72GHz

- Corrugated horn
- Cooled receiver
- Optical Fibre for IF
- Line, Pulsar, VLBI

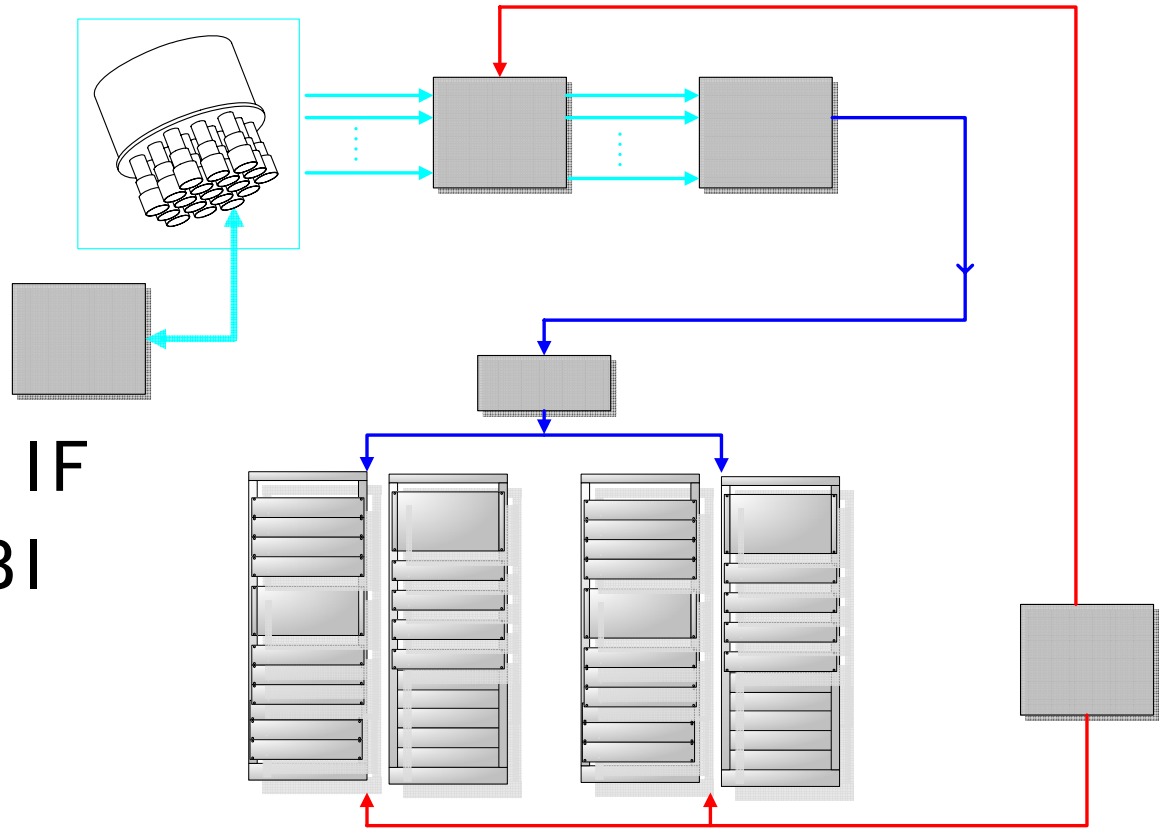
- Tsys～ 25K



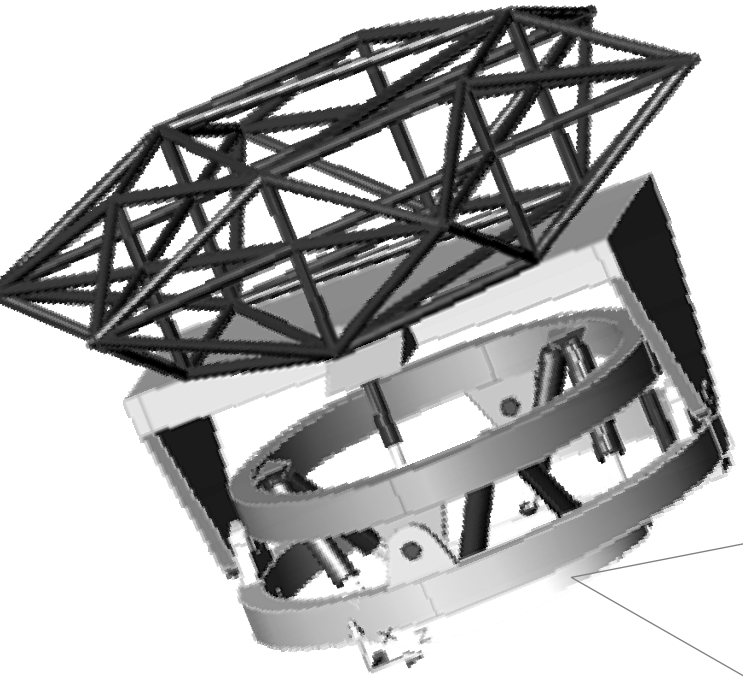
Multi-horn 1.23-1.53GHz

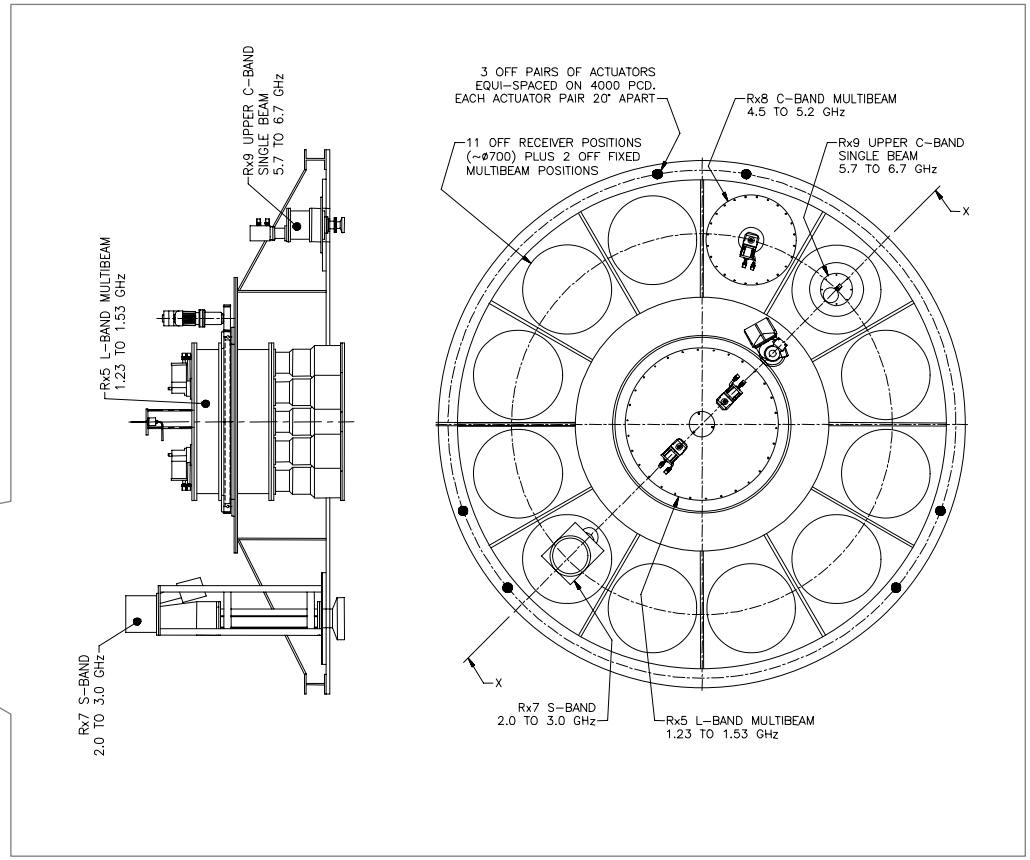
- Coaxial feeds
- No.of beams: 19
- Cooled receiver
- Optial Fibre for IF
- Line, Pulsar, VLBI

- Tsys ～ 25K



Receive layout design (2000 & 2006)

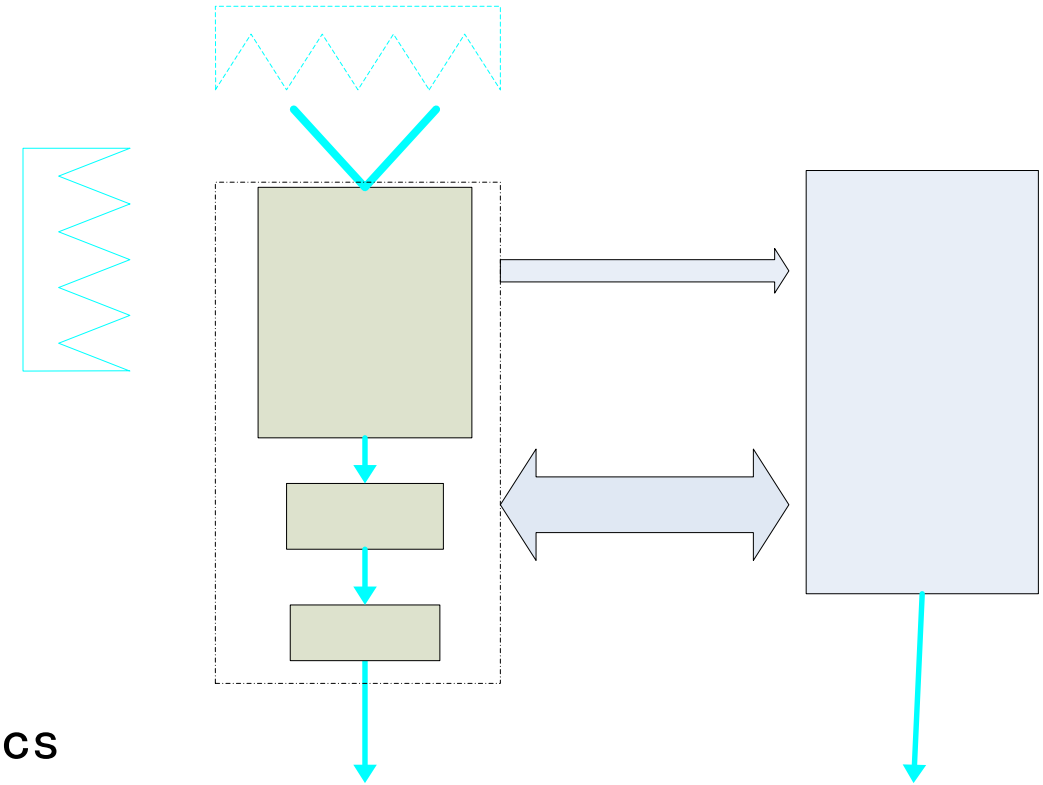




Receiver Monitoring & Diagnostics

- Temperature
- Vacuum
- Power supply
- IF bandpass
- RFI spectrum
- Tsys
- Aeff

- Status of the receiver, remote trouble diagnostics



Summary of the layout

- Based on existing, proven design
- Frontend and backend
- Weight and size
- Important input to the focus cabin design

Recommendations from the International Review

- Large-scale HI surveys
- Pulsar Surveys
- Pulsar timing and emission properties
- Search for extrogalactic mega masers.
- EoR
- VLBI
- High redshift HI absorptions
- Diffuse emission from the Galaxy
- SETI
- Planetary radar

Next step, development work

- Lesser sets of receivers, wideband feeds/receiver
- Multi-horn /PAF at core band

  focal field analysis
- Multi-beam for incoherent radar
- IF transmission, experiment on the stability of the signal transmission
- Using the whole 500m aperture
- Digital backend

Low frequency receiver

Frequency coverage:
70MHz ～ 1GHz

VLA: low frequency@74MHz

Frequency coverage:

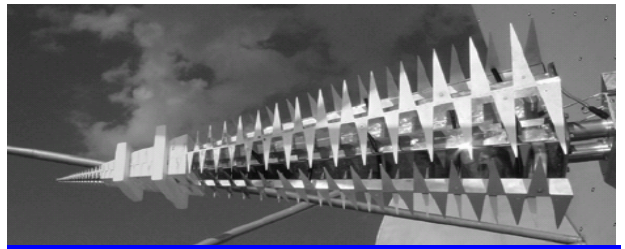
70 – 140MHz

140 – 280MHz

280 – 560MHz

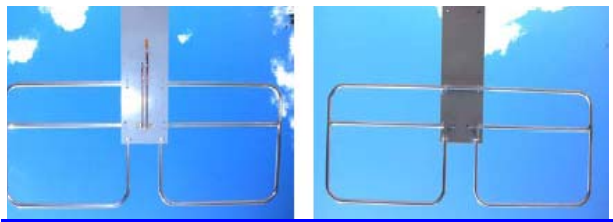
560 – 1024MHz

70 – 1000MHz



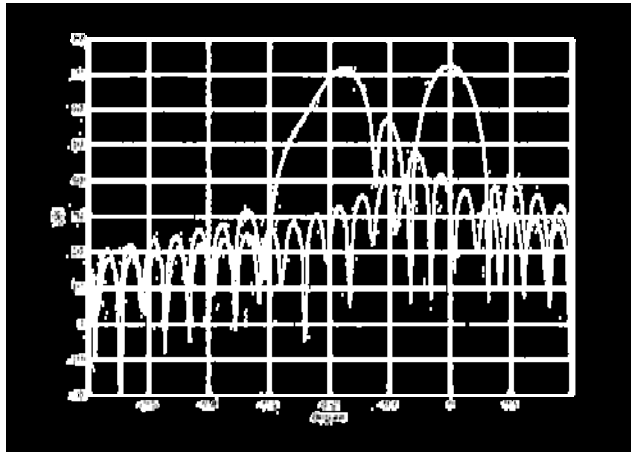
ATA 0.5 – 11GHz

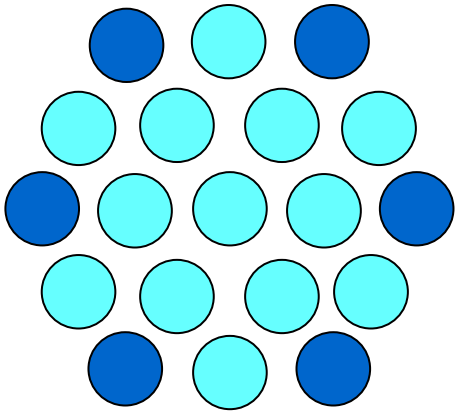
LOFAR 120 – 240MHz

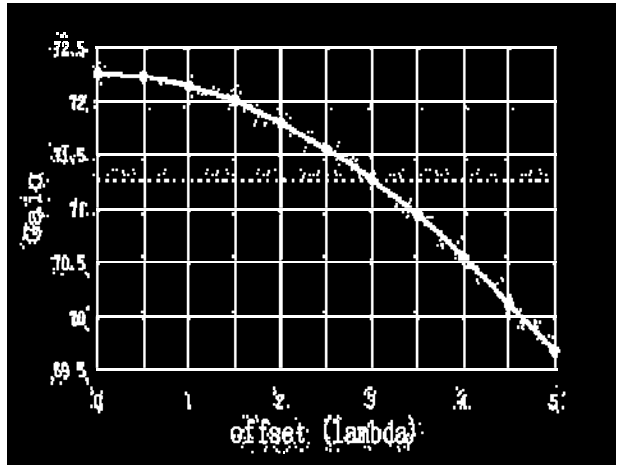


WSRT 115 – 180MHz

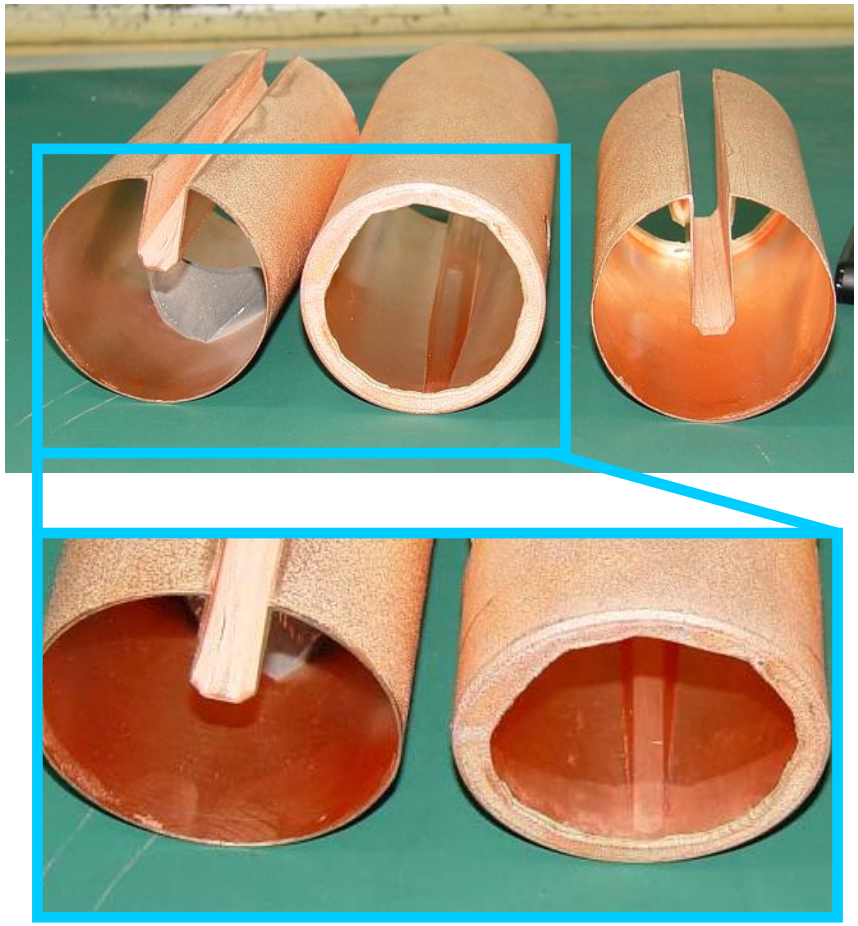
Mulbi-beam at L-band







multi-horn, OMT



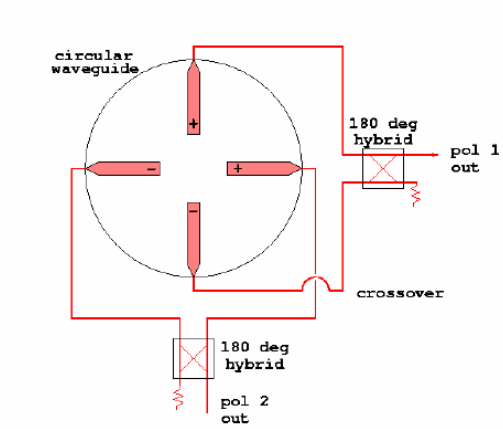
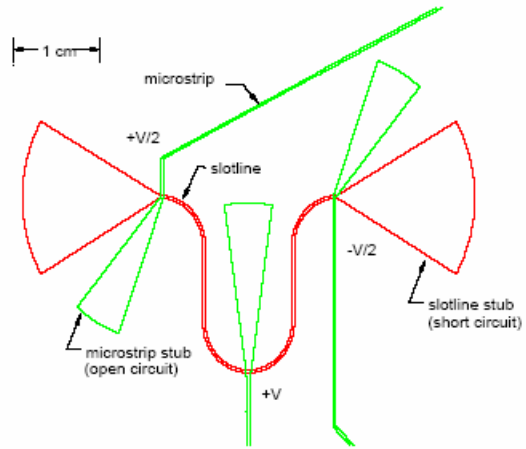
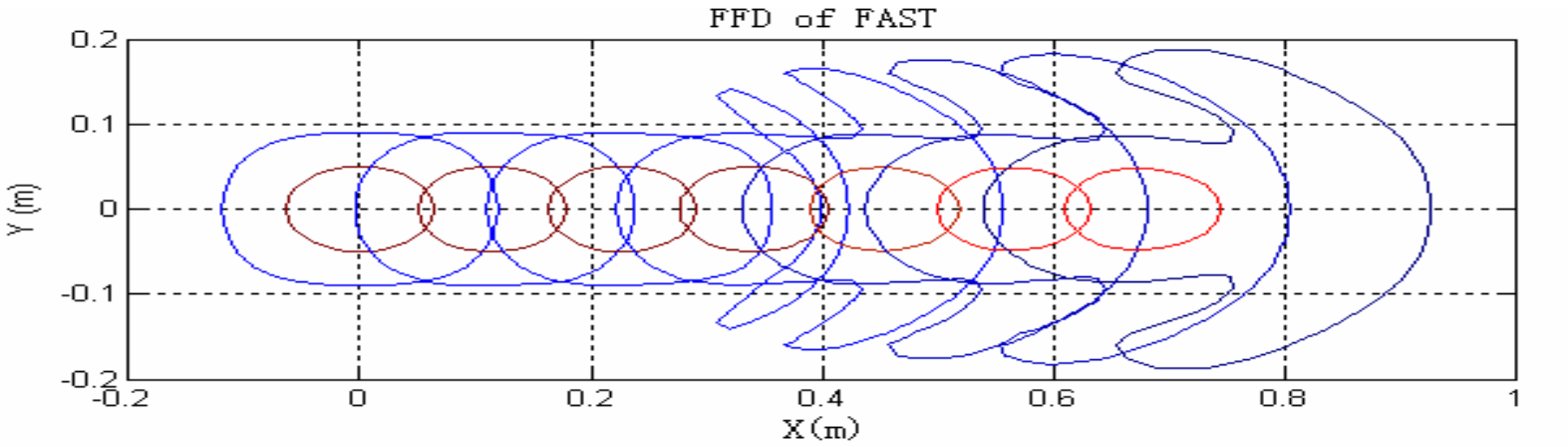


Figure 1. Basic design of the orthomode transducer.



Focal field distribution

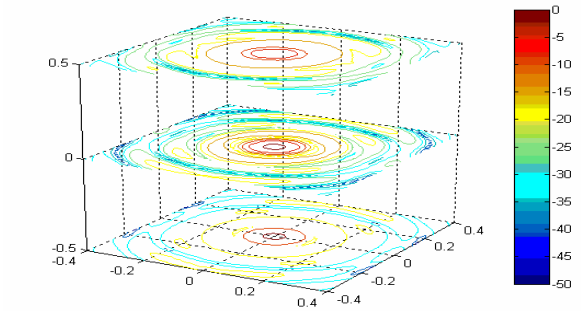


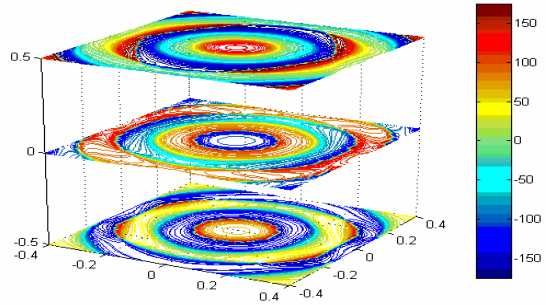
Power

Phase

θ =0deg

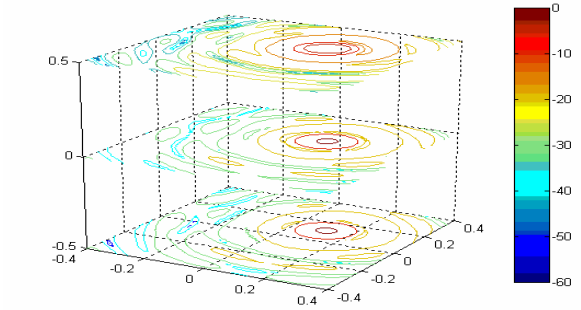
ϕ =0deg

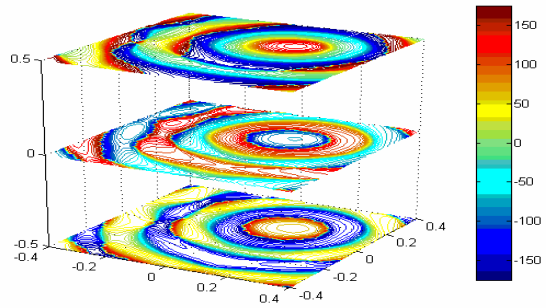




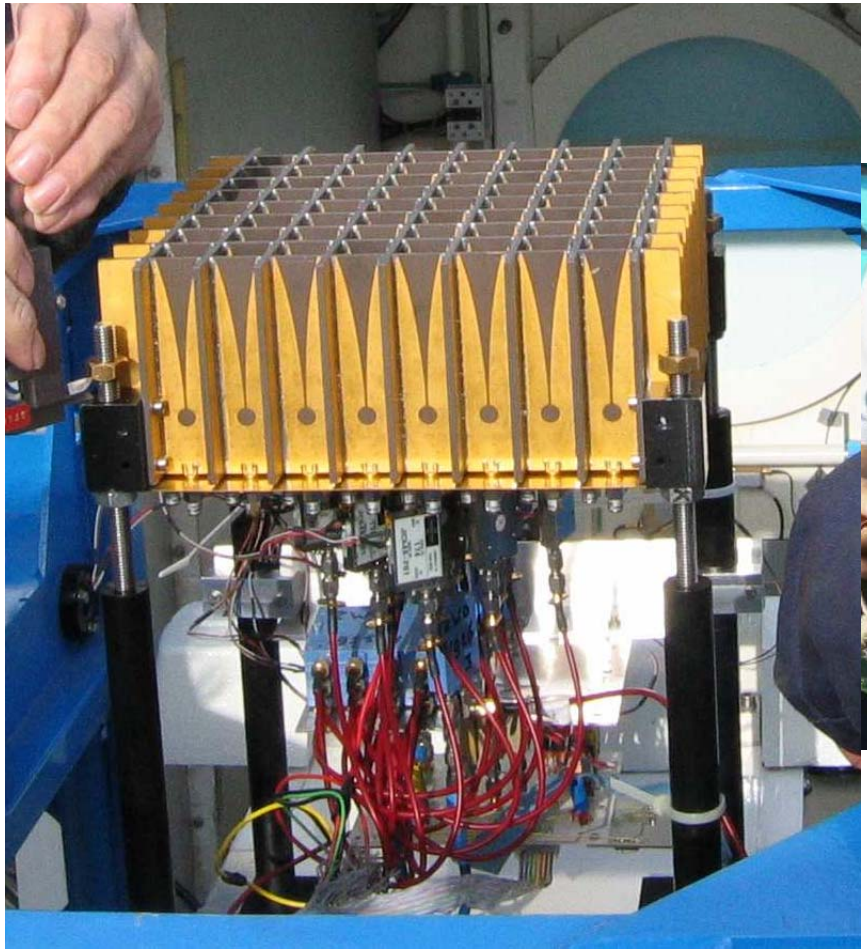
θ =0.566deg

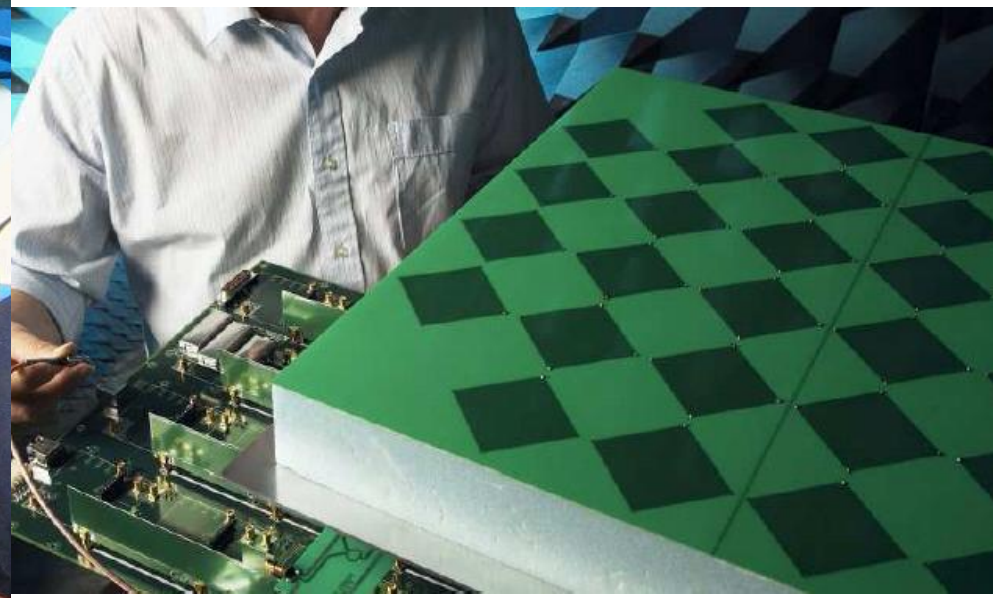
ϕ =45deg



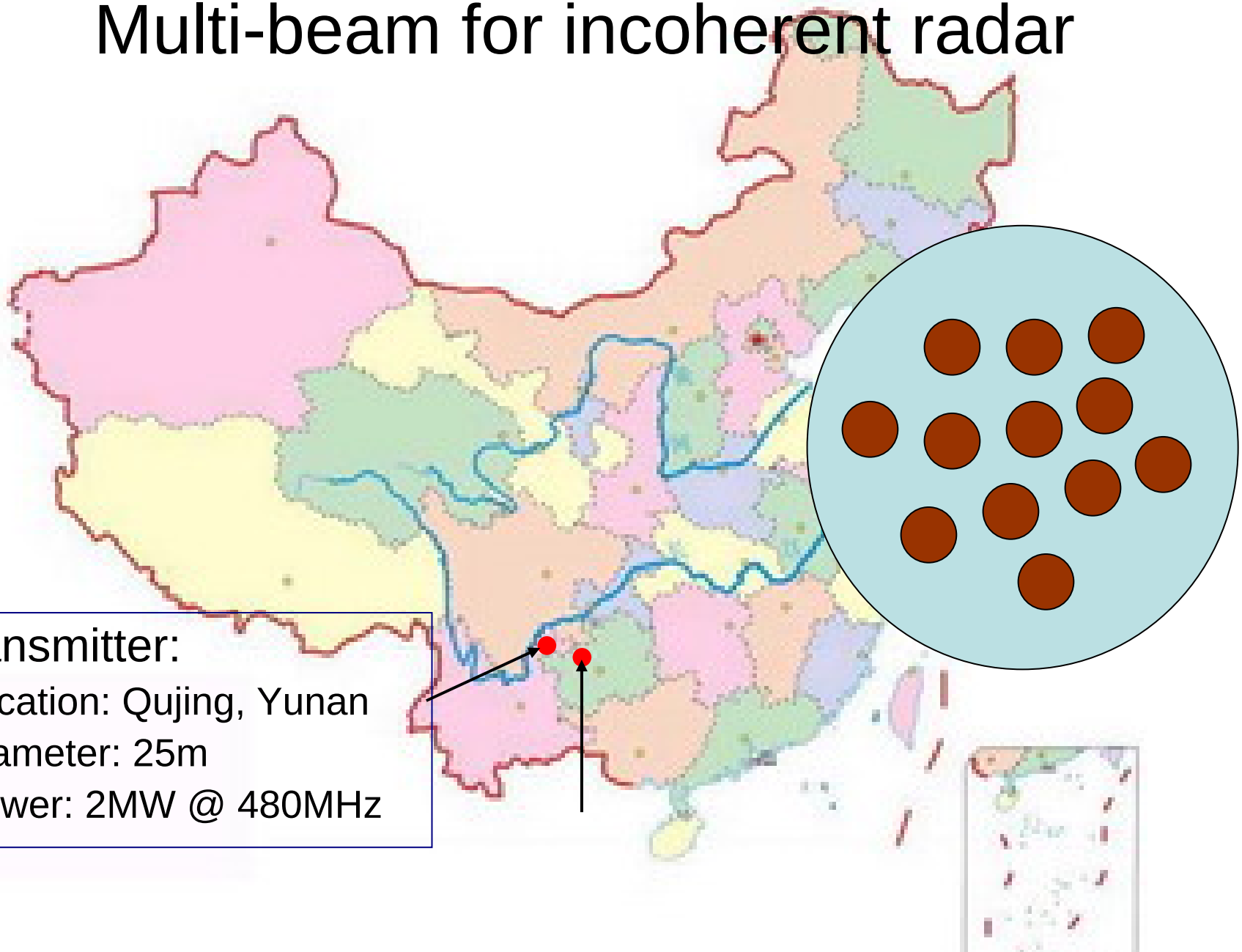


PAF on FAST





Multi-beam for incoherent radar

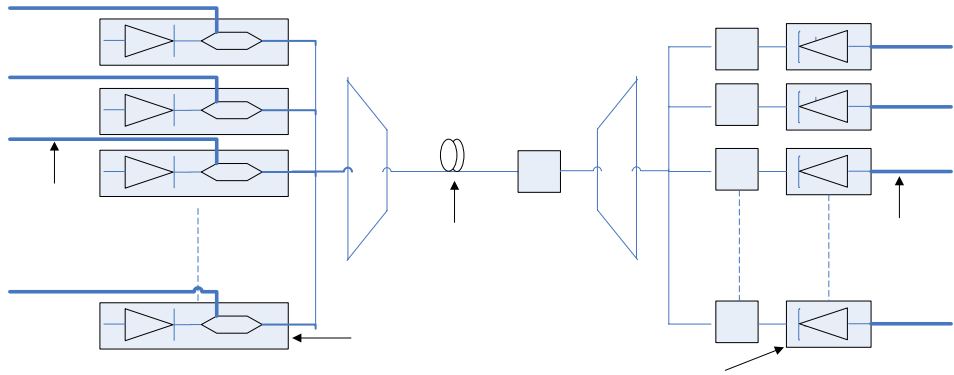


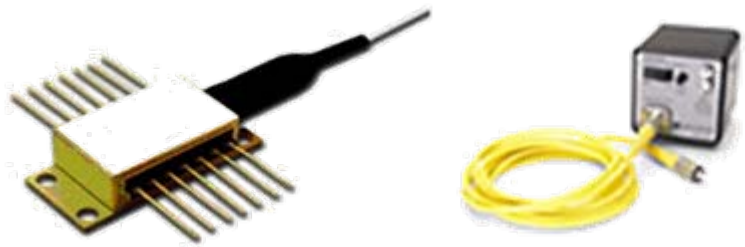
Transmitter:

- Location: Qujing, Yunan
- Diameter: 25m
- Power: 2MW @ 480MHz

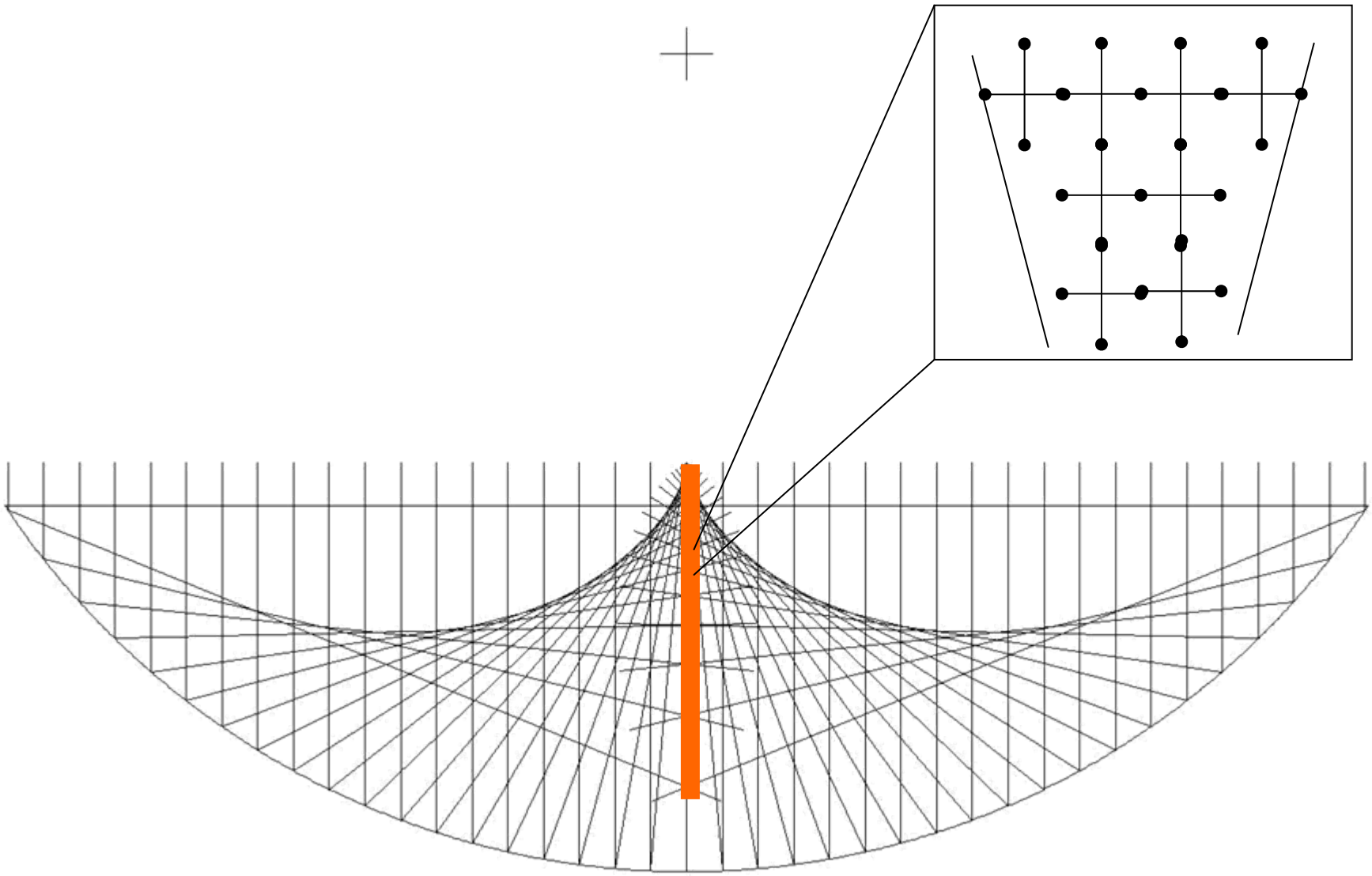
IF transmission

- Amplitude & Phase
- Linearity to strong signal
- Lifetime





Using the whole 500m



Digital Backend

- Current fast development in this field

  CASPER

  ATNF PDFB

  Digital BBC for VLBI

- As for FAST(no correlator)

  Comercial A/D+FPGA + PC-cluster

  might also be possible.

CASPER

CENTER FOR ASTRONOMY SIGNAL PROCESSING AND ELECTRONICS RESEARCH

casper.berkeley.edu

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Goals

The goal of CASPER is to streamline and reduce the current radio astronomy instrumentation design flow through the development of an open-source, platform-independent design approach.

This incorporates reconfigurable, modular, easily upgradable hardware with standard, parameterized design libraries that abstract away the underlying details of the system.

Design simplifies to creation of block diagrams of components from standard libraries and the designer.

Future Plans

CASPER has several upcoming projects, which include development of economical spectrometers for demonstration and astronomy education, revision of general-purpose signal processing libraries, and development of a new generation of the BEE2 family of boards.

Implementation of a fully parameterized, packetized correlator will begin after development of eight-antenna and thirty-two-antenna,

Whats New

New Memo
April 23, 2008
A feasibility study of a 4 Gbps data recorder for VLBI
(Jouko Ritakari et al.)

New Photo Gallery - BAPP
April 20, 2008
Berkeley ATA Pulsar Processor Deployment Gallery
(Peter McMahon and Joeri van Leeuwen)

Summer 2008 Workshop Registration Open
March 26, 2008
Sign-Up Here
(Dan Werthimer)

New Memo
March 04, 2008
"10GbE NIC Benchmarking"
(J Manley, T Filiba, D Werthimer)

A New Approach to Radio Astronomy Signal Processing:
Packet Switched, FPGA-based, Upgradeable, Modular Hardware and Reusable, Platform-Independent Signal Processing Libraries

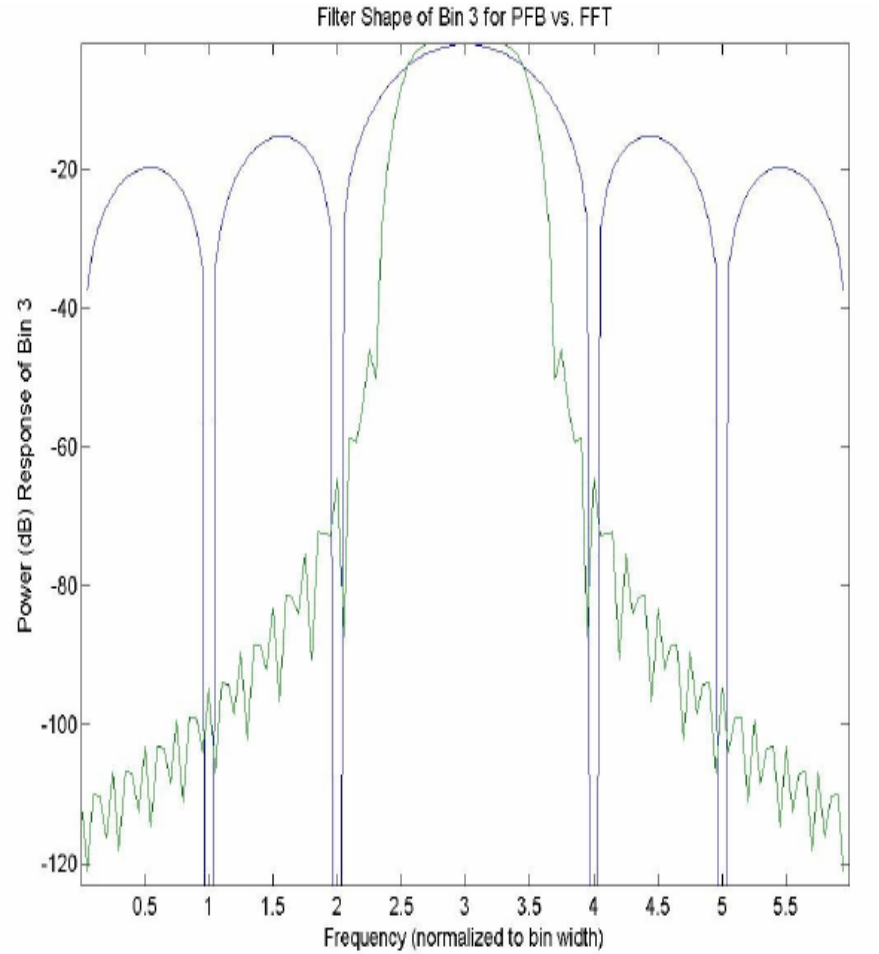
Aaron Parsons[1],
Don Backer[1], Chen Chang[4], Daniel Chapman[5], Henry Chen[2], Pierre Droz[2,4],
Christina de Jesus[5], David MacMahon[3], Andrew Siemion[5], Dan Werthimer[2], Mel Wright[3]

[1] *University of California, Berkeley Astronomy Dept.,*
[2]*University of California, Berkeley Space Sciences Laboratory,*
[3]*University of California, Berkeley Radio Astronomy Laboratory*
[4]*Berkeley Wireless Research Center*
[5]*University of California, Berkeley*

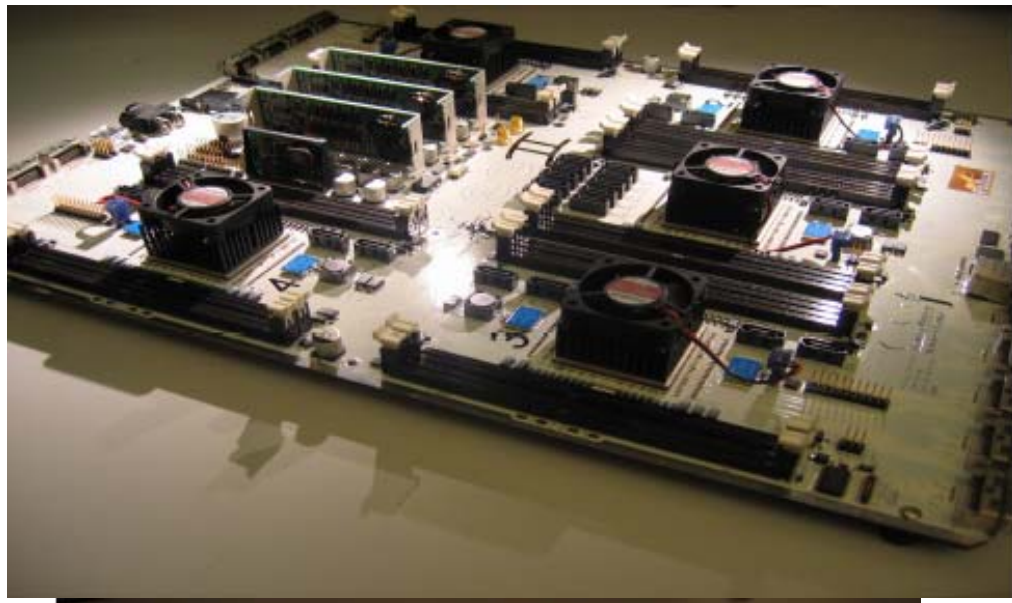
ABSTRACT

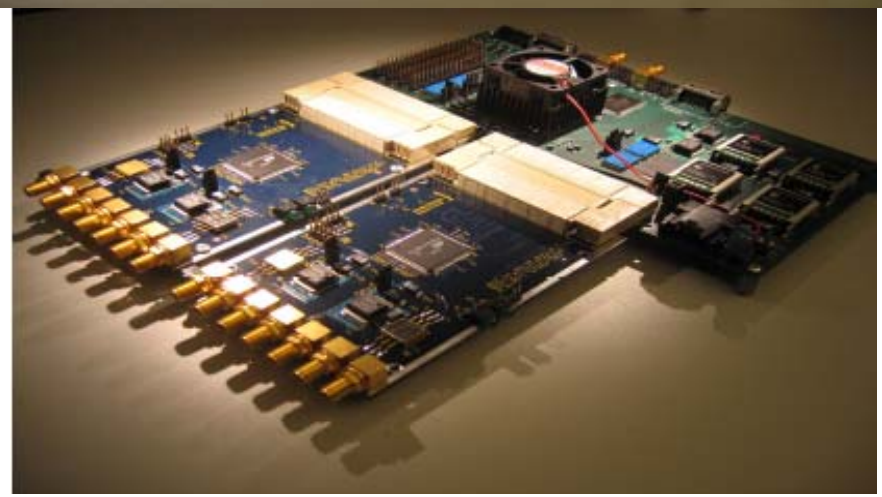
Our group seeks to revolutionize the development of radio astronomy signal processing instrumentation by designing and demonstrating a scalable, upgradeable, FPGA-based computing platform and software design methodology that targets a range of real-time radio telescope signal processing applications. This project relies on the development of a small number of modular, connectible, upgradeable hardware components and platform-

PFB vs. FFT



BEE2, IBOB





FPGA based backends

- PDFB @ ATNF, timing residual~50ns
- Digital BBC for VLBI

COBRA, CPSRII

Wideband Digital Receiver – Generator – VME/VXS

ASBus Trigger, and Clock Distribution

External Clock & Trigger

Analog IO Mezzanines each with 2GS/s 10-bit ADC or 1.2 GS/s 14-bit DAC

Auxiliary IO Mezzanine

Optical Data Links 2 x 4.25 Gbps sFPDP

Jet*Speed II* COS201

Jet*Speed II* MAC200

TSI148VME bus interface

VITA 41 VXS 8 x 3.125 Gbps

Virtex 4 SX55 FPGA Processing

Virtex 4 FX100 FPGA Communication

2 banks of 32 M x 64 bits DDR2 SDRAM

Broadband FFT Spectrometer in Radio Astronomy

Purple Mountain Observatory – China
KOSMA Observatory, ETH Zurich, University of Applied Science - Switzerland
CSIRO, University of Tasmania – Australia
Max Plank Institute – Germany
Tsukuba Observatory, Osaka Prefecture University, Nagoya University – Japan

应用对象和要求：
天文台或者空间技术研究所使用的**射电望远镜**需要对射电系统中的中频信号进行**实时FFT信号处理**。

系统配置：

- 采集板卡　U1080A-001
- IP-Core FFT　U1080A-FFT
- cPCI主机控制器　U1056A-300
- cPCI工业机箱　U1056A-C31　（3槽）
  （总价约 4万美金）

技术特点和指标：

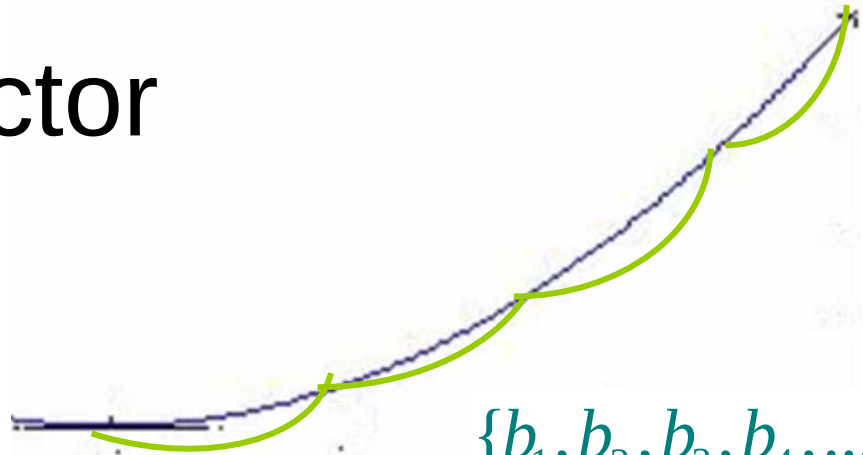
- 提供**实时FFT信号处理功能**（信号在处理过程中无丢失）
- 采样率**400MHz到1GHz**，处理点数：32K个点，
- 信号处理**带宽200MHz到500MHz**信号；频谱通道为16K个；
  频谱分辨率：12.208KHz到30.52Khz
- 提供**累计平均功能**，帮助用户将信号从噪声中累计检测出来。

A solution based on Commercial Available Products

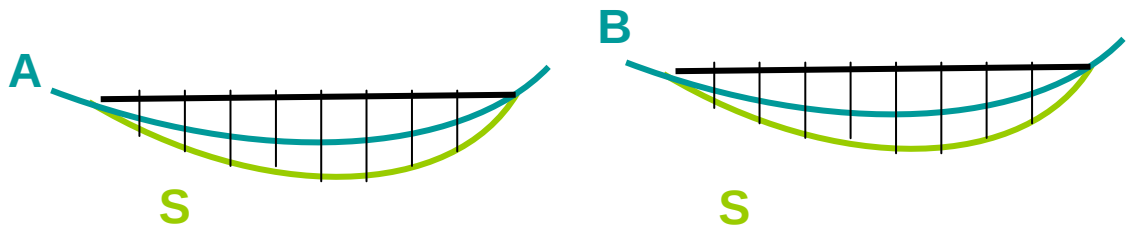
- A fast A/D with on-board FPGA
- Polyphase Filterbank
- Data distrubution via network
- Data processing by PC-cluster

Thanks

Active main reflector



$\{b_1, b_2, b_3, b_4, \ldots, b_n\}$



A $\{a_1, a_2, a_3, a_4, \ldots, a_n\}$

S $\{s_1, s_2, s_3, s_4, \ldots, s_n\}$

$$Arms = \sqrt{\frac{(a_1 - s_1)^2 + (a_2 - s_2)^2 + (a_3 - s_3)^2 + (a_4 - s_4)^2 + \ldots + (a_n - s_n)^2}{n}}$$

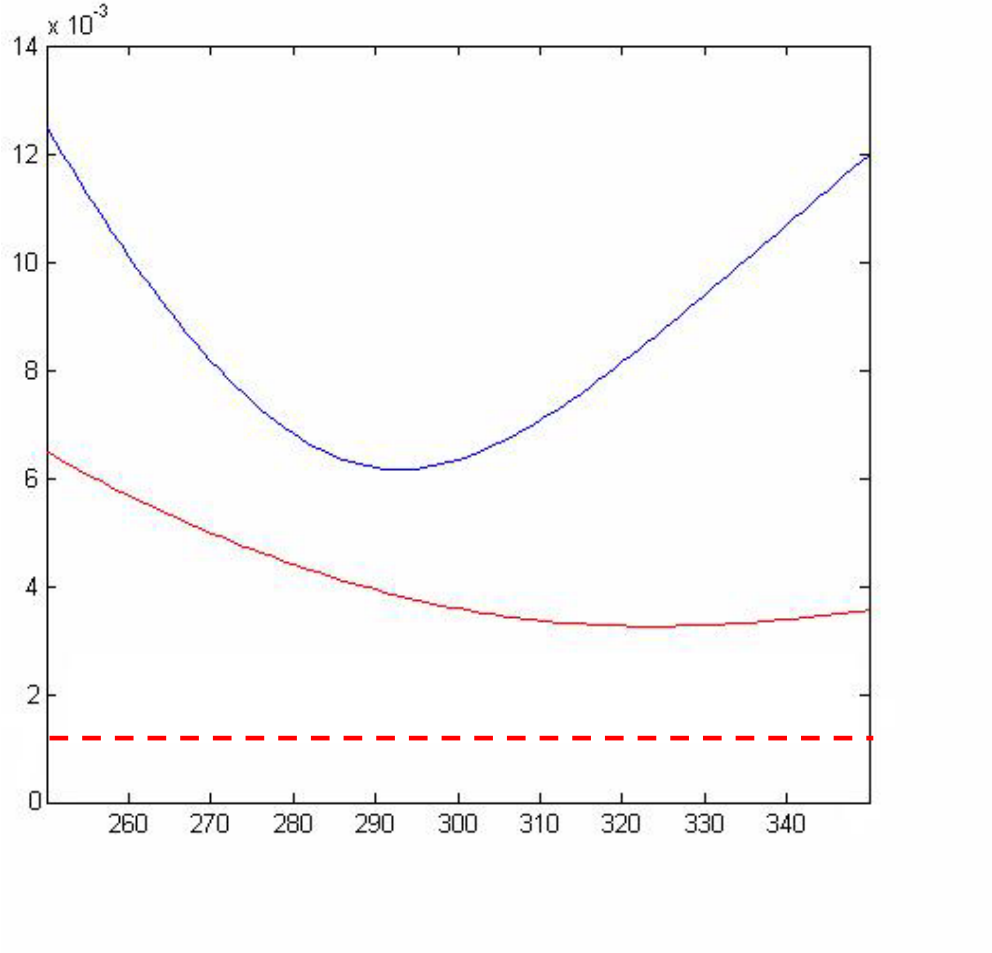
$$Brms = \sqrt{\frac{(b_1 - s_1)^2 + (b_2 - s_2)^2 + (b_3 - s_3)^2 + (b_4 - s_4)^2 + \ldots + (b_n - s_n)^2}{n}}$$

$$\vdots$$

$$Mrms = \sqrt{\frac{(m_1 - s_1)^2 + (m_2 - s_2)^2 + (m_3 - s_3)^2 + (m_4 - s_4)^2 + \ldots + (m_n - s_n)^2}{n}}$$

Deviation from the paraboloid

- Spherical: 2-3mm
- Optimized: ~1mm



Focus Cabin Suspension

- **Position error**

  <10mm