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Session II. Engineering Collaboration Items

FPGA backend for a wideband reciever system

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Kagoshima university, Japan

SKA-JP Engineering Working Group

- SKA-JP EWG formed in 2012 (this year)
- Sub Working Groups
  - Digital Signal Processing (HN)
    F-engine with ROACH
  - Software (Tomoharu Kurayama)
    Tool for Faraday tomography
  - Feed for WBSPF (Hideki Ujihara)
    Decade band feed

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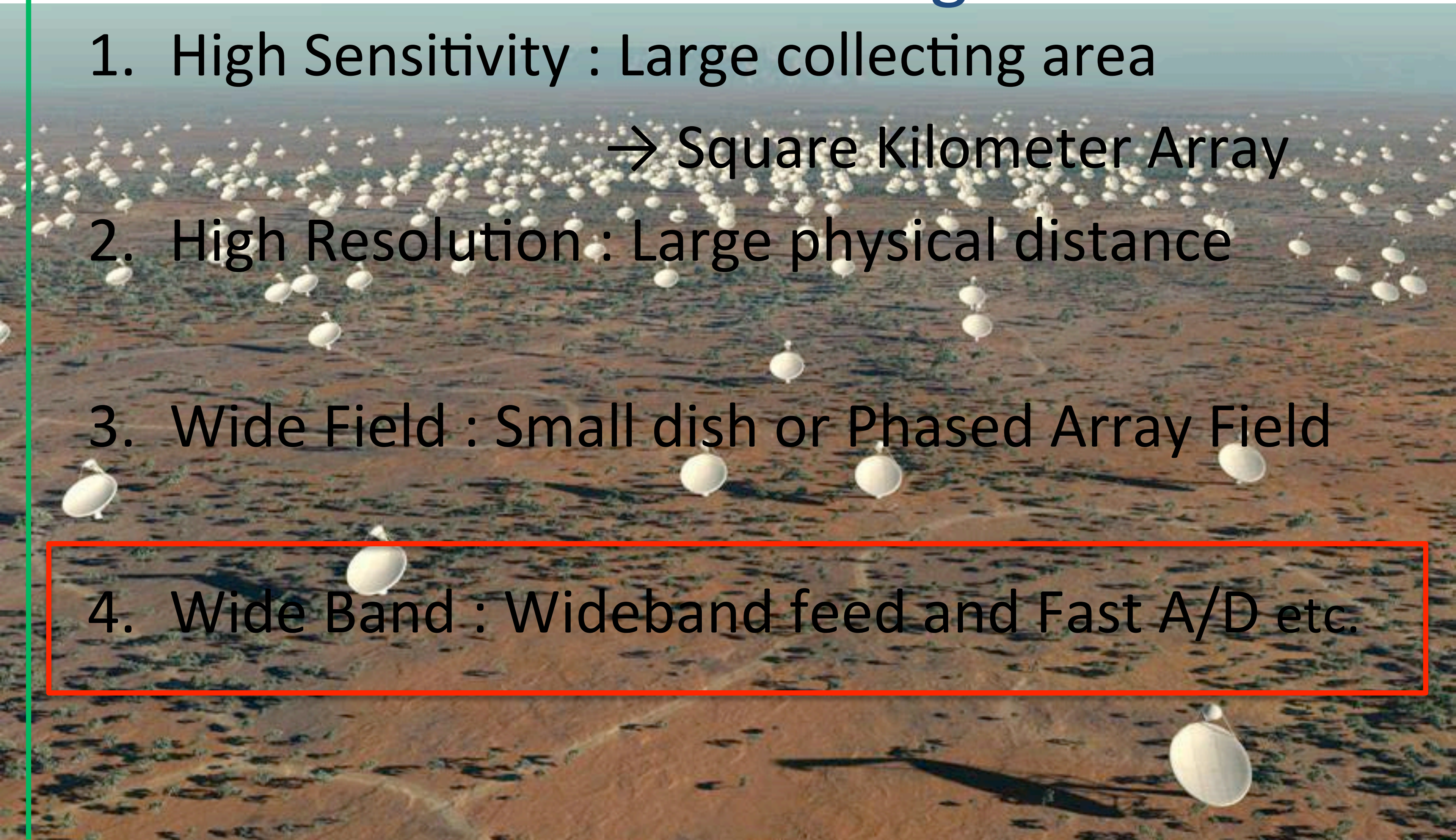
SKA
SQUARE KILOMETRE ARRAY

Primary Characteristics of SKA and Related Challenges



1. High Sensitivity : Large collecting area

   → Square Kilometer Array

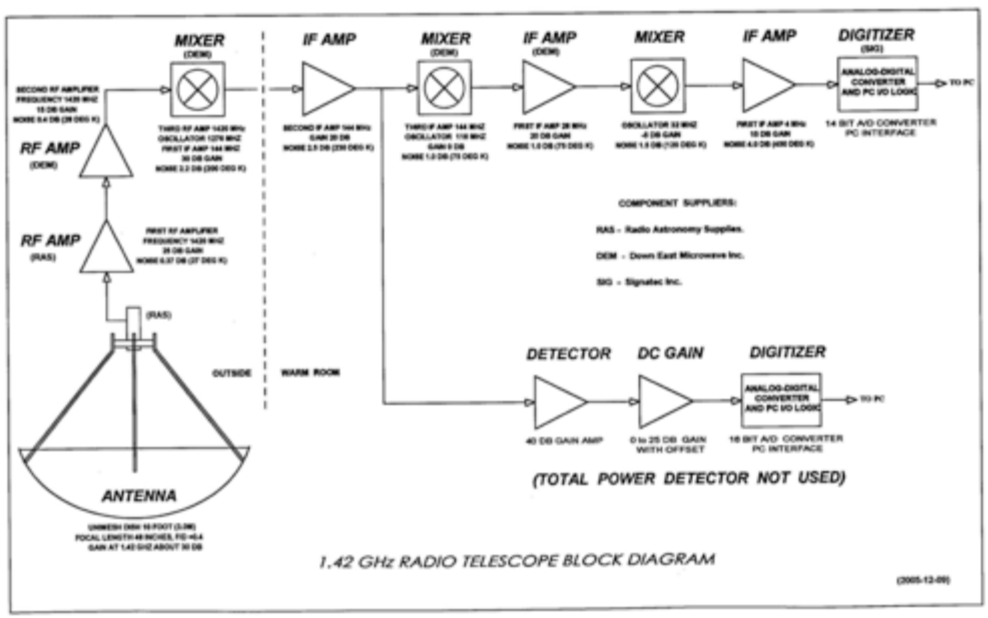
2. High Resolution : Large physical distance

3. Wide Field : Small dish or Phased Array Field

4. Wide Band : Wideband feed and Fast A/D etc.

What’s important for Wideband

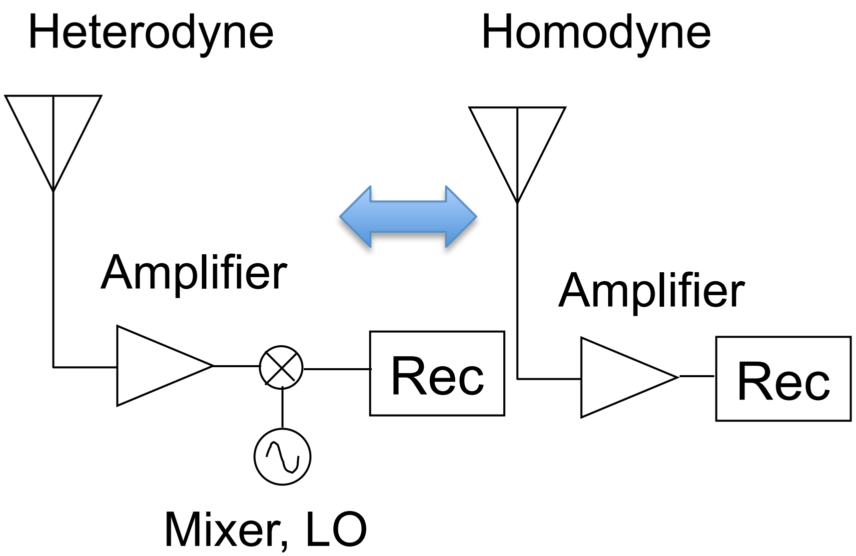
1. Frequency response in analog components
2. Sampling rate at Analog-to-Digital converter



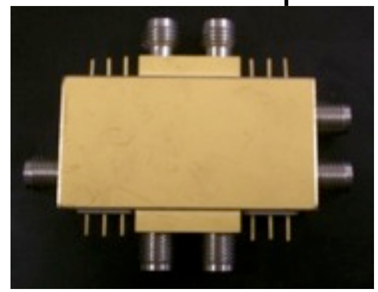
The 1.42 GHz radio telescope block diagram, courtesy of Fred Babott.

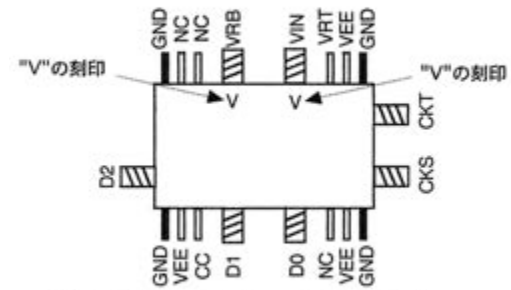
Less analog components and faster A/D

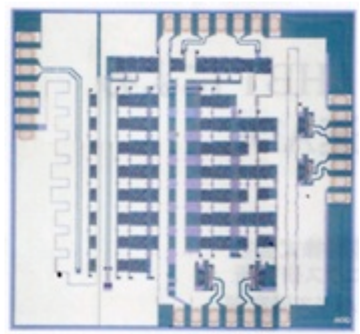
Homodyne receiver with Fast A/D converter



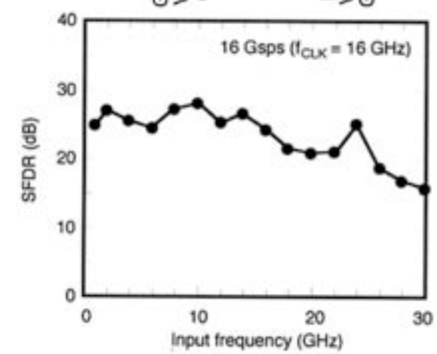
Fast InP HBC 3bit sampler （Kawaguchi@SKA-JP WS 2008)





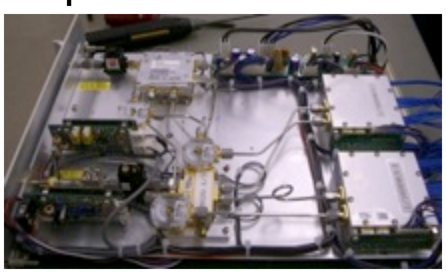


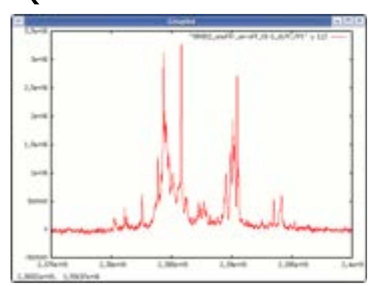
(3 mm × 3mm)



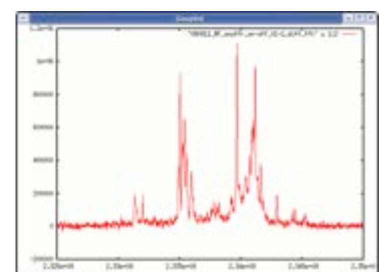
NTT Photonics Laboratory

Experiment





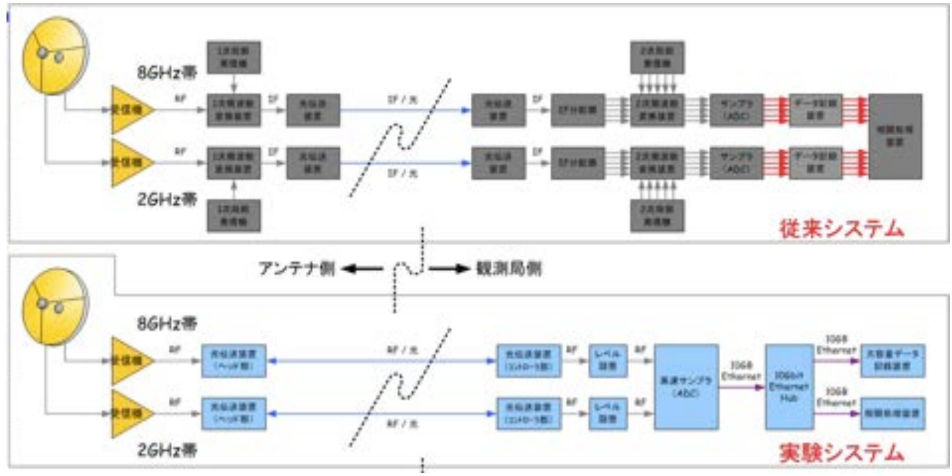
Spectra obtained with heterodyne receiver (fLO=(16.85+3)GHz、fIF=2.2-2.6GHz, fsample=8.192GHz)

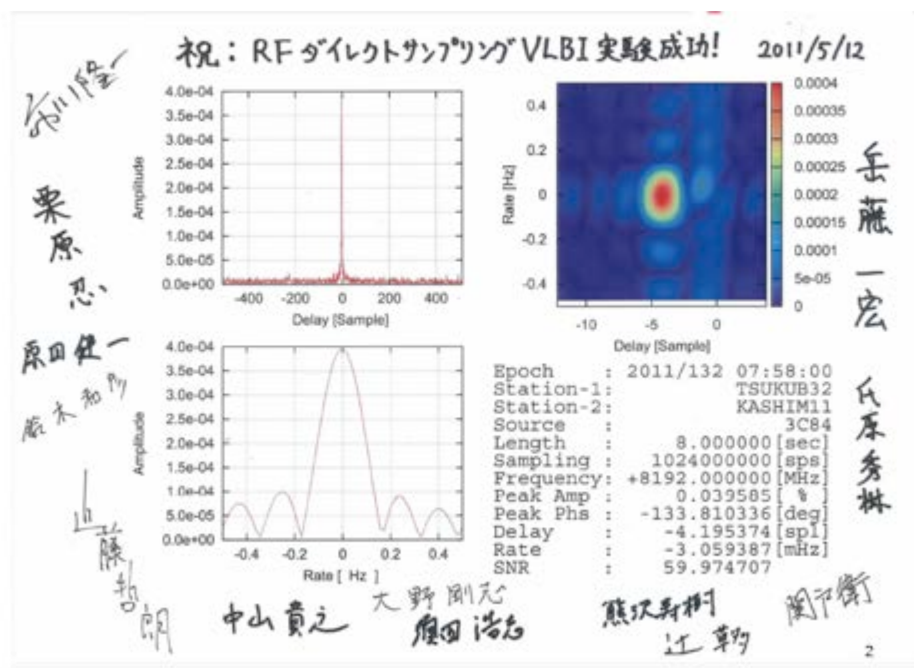


Spectrum obtained with homodyne reciver (fRF=20.480-24.576GHz, fsample =8.192GHz, BW=4.096GHz)

VLBI experiments with Homodyne

Kashima 11m





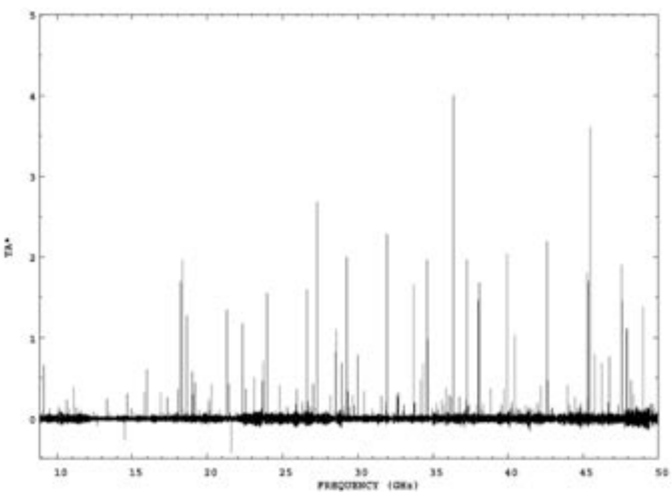
Homodyne Receiver System in the Future

- Experiments shows that homodyne receiver system is promising for the future radio telescope
- Wideband of Octave band (1:2) – Decade band (1:10) (Century band (1:100)?) would be common

Scientific Requirement

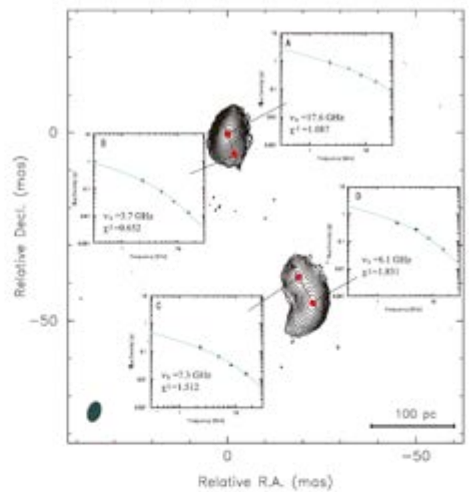
- Wideband spectrum

Line observation



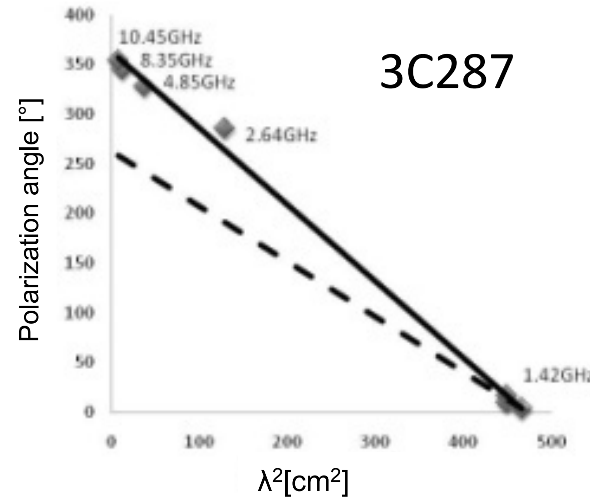
Ultra wideband Line survey for TMC-1 in 8-50GHz(Kaifu et al. 2004)

Cont. observation



Wideband SED (2.2-15.3GHz) of AGN CTD93 (Nagai et al. 2006)

Polarization observation



Polarization angle over wideband→More accurate rotation measure (slope)

- Higher sensitivity： $\Delta T \propto B^{-1/2}$
  - ･Distant faint object can be detected
  - ･Increase of reference source for astrometry

Wideband would be great but ...

Another issue shows up:

Bandwidth ratio to observed frequency is not negligible anymore.

For example:

The case of multi-line observation:

HI: f_0=1.4GHz, Δf=48kHz → Δv=Δf/f_0=10km/s

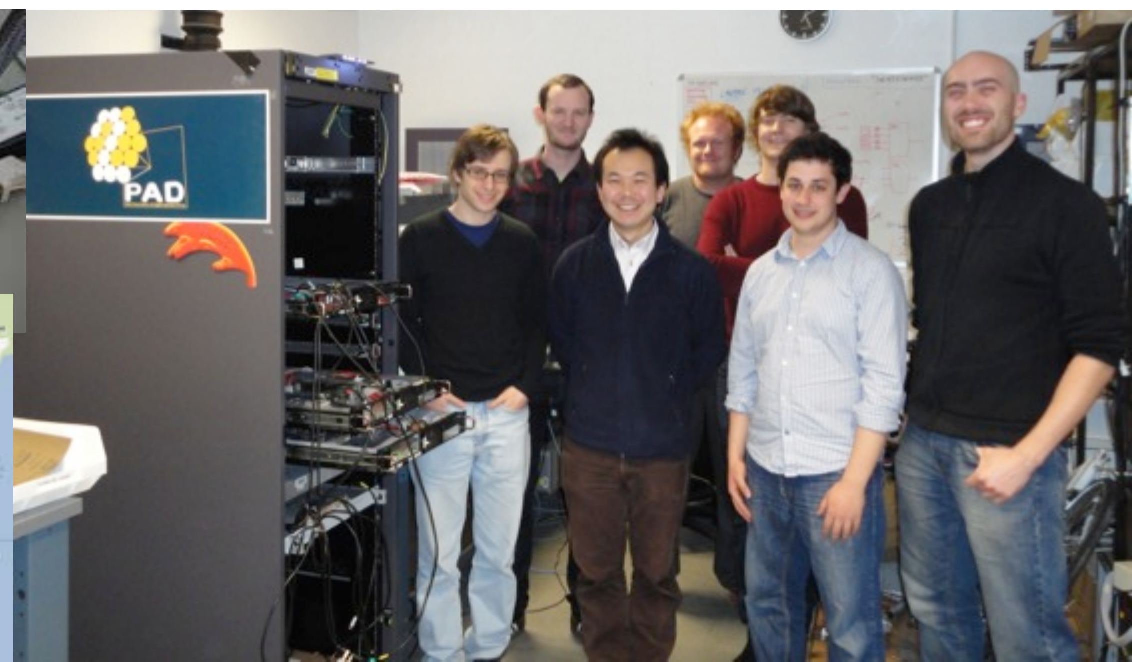
CH_3OH: f_0=6.7GHz, Δf=48kHz → Δv=Δf/f_0= 2km/s

If frequency coverage is 1-8GHz, 150000ch is necessary (required velocity resolution: 10km/s), but it's oversampling for the high frequency.

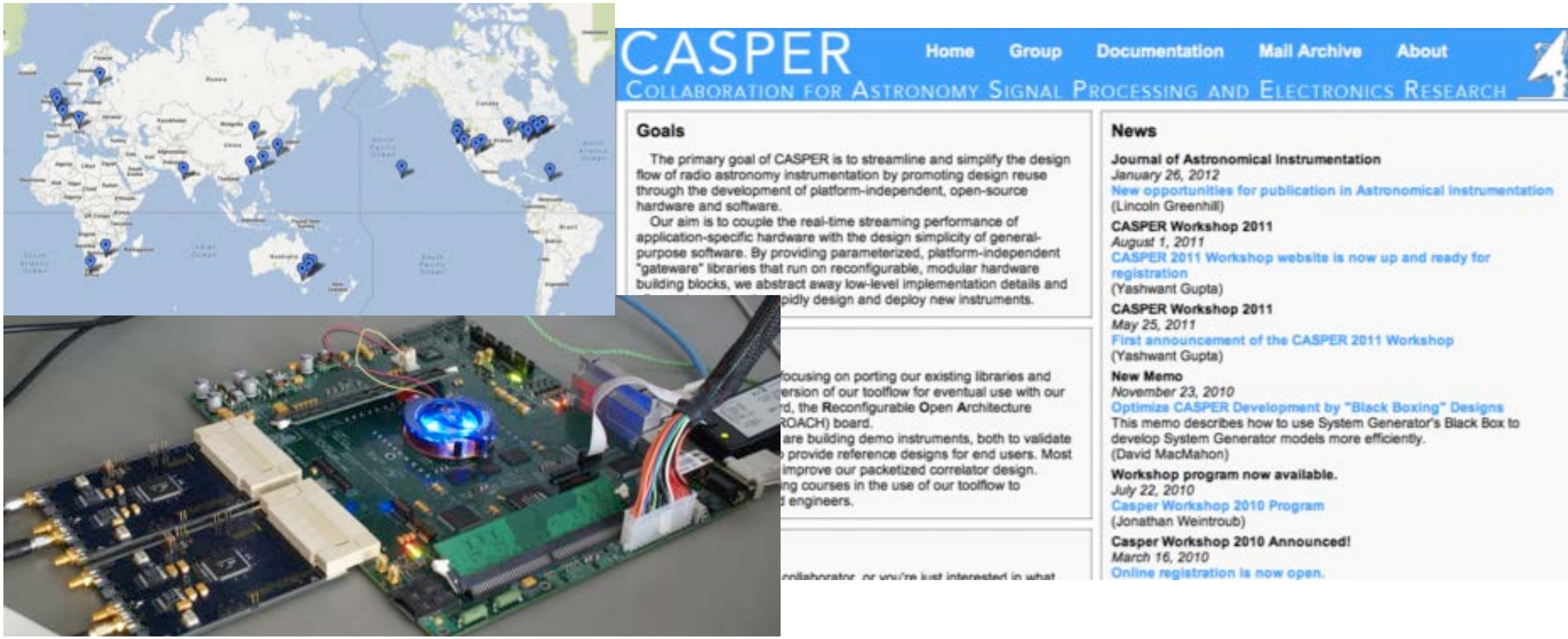
Optimized channelization

Our current interest

- Optimized channelization (ex. $\Delta f/f_0$ =const.) in F-engine using ROACH board (Collaboration with Oxford)
- 2 ROACH boards were recently delivered to Kagoshima university.



What is ROACH



- CASPER is a project to develop open-source hardware and software.

  → Good starting point for international collaboration

- ROACH (**R**econfigurable **O**pen **A**rchitecture **C**omputing **H**ardware) is an FPGA board developed by CASPER project

Comparison of Rival Architectures

FPGA (ROACH)	GPU (Tesla C2070)	CPU (i7 3960X)
High I/O (GbE, InfiniBand)	Low I/O (PCIe)	Low I/O
Low power consumption (15 W)	High power consumption (225W)	High power consumption (130 W)
Difficult to program (HDL)	Easy to program (CUDA, OpenCL)	Easy to program (multiple languages)

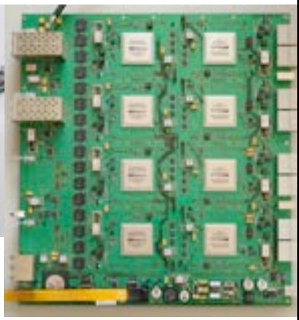
Slide from Chris Taylor, “Thoughts on CASPER 2011”, University of Manchester GPU Club

- ASIC has the lowest power consumption and good I/O as FPGA. Quite difficult to develop.

ROACH vs UniBoard

- ROACH and UniBoard have the same philosophy:
  “open-source” library
- UniBoard has the better cost and power performance
- ROACH seems still easier to use
  ROACH : MATLAB/SIMULINK
  UniBoard: HDL
- ROACH is easier to start
  We tried to purchase UniBoard last year but was not ready
- CASPER international team is well organized

	ROACH	UniBoard
FPGA chip	1 x Xilinx Virtex 5	8 x Altera Stratix IV
Leading Institute	UC Berkley	ASTRON
Cost / chip	$5,500	$2,700

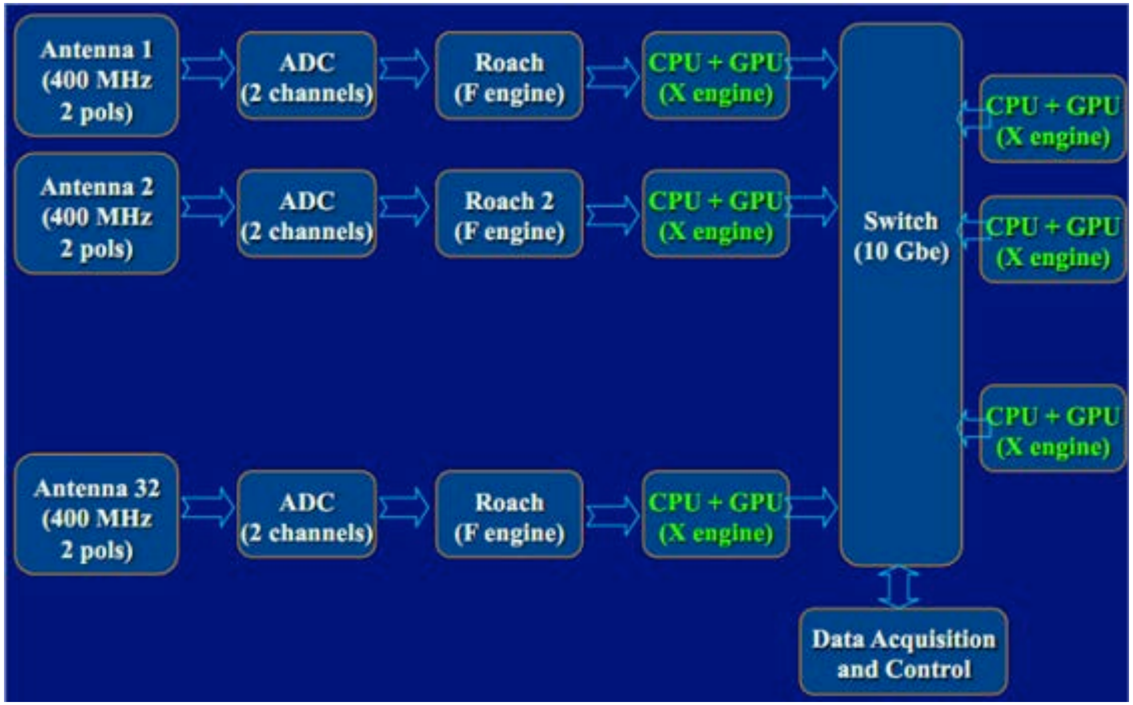


It seems good to start DSP development with ROACH and copy to UniBoard in the future

Possible EA collaboration

- Fast A/DC board (Taiwan ?)

  First step: just use ADC1x5000-8, Second step: development of faster A/D ?
- Hybrid architecture (F-engine with FPGA and X-engine with GPU) (Korea ?)
- And more ...



Yashwant Gupta, Next Generation Digital Back-ends at the GMRT

- ✧ F Engine:
  - ✓ FFT
  - ✓ Channelise
  - ✓ Packet data
- ✧ X Engine:
  - ✓ Correlate
  - ✓ Integrate
  - ✓ Dump data

Summary

- SKA-JP EWG formed this year
- The keyword is “Wideband” and fast A/D is the key component.
- The homodyne receiver system might be common technique in the near future
- SKA-JP DSP team started developing F-engine using ROACH board.
- Collaboration related to A/D and hybrid-architecture correlator.