The Gala-V, our unique solution for the VLBI2010

Kazuhiro Takefuji
On behalf of VLBI Group of NICT/Kashima
“Gala-V” is **Galapagos VLBI**

- Galapagos means “evolutionary", “individual”, and “unique” in Japan.
- Our proposed system is quite unique, so we named our project “Galapagos VLBI”, shortly “Gala-V”

We want to survive somehow in an extreme condition!
Contents

1. NICT VLBI project
2. Interference survey
3. frequency channels allocation
4. Gala-V feed horn
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VLBI mission in NICT

- NICT keeps the National Time Standard of Japan.
- VLBI technology are used for frequency transfer (officially)
- We are also Technical development center (TDC) of IVS, Full (or semi) compliance to the VLBI2010 is required.
Co-observation for boosting a sensitivity with large antenna is required. However much better precision ($1.e^{-16}$) is required! Delay caused by 1m gravity difference on the ground by general relativity. Better SNR and wider bandwidth like VLBI2010!!
Interference measurement
RFI Survey
2-18GHz

3GHz HPF was inserted before the LNA

Kashima 2012 Jul 4

Tsukuba 2012 Jul 11

Koganei 2012 Jul 5

2GHz 18GHz
Signal from communication satellite measured by 1.5m antenna
RFI survey result

• Interferences lower than 3GHz are seriously strong even if they are filtered.
• Strong RFIs in 4.2-4.35GHz, 5.3-5.4GHz, 9.3-9.6GHz
• Signal of comm/broadcast satellite is allocated in 11-13GHz (world wide?)
Selection of Frequency

• By taking into account
  – RFI survey results and Comm./Broadcast Satellites.
  – Low SNR with small diameter (1.5m) antenna
  – Good delay resolution (group delay) for T&F transfer
  – And
My boss Sekido-san said to me...

We don’t have money! Decide fixed quad-band channels!!

OK! I will!
Candidates for the frequency sequence with the zero redundancy array

<table>
<thead>
<tr>
<th>Separation (MHz)</th>
<th>Ambiguities(ps)</th>
<th>Ratio of 1:3:2 [GHz]</th>
<th>Ratio of 2:3:1 [GHz]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000MHz</td>
<td>1000ps</td>
<td>3.0  4.0  7.0  9.0</td>
<td>3.0  5.0  8.0  9.0</td>
</tr>
<tr>
<td>1250MHz</td>
<td>800ps</td>
<td>3.0  4.25 8.0  10.5</td>
<td>3.0  5.5  9.0  10.5</td>
</tr>
<tr>
<td>1500MHz</td>
<td>666.66ps</td>
<td>3.0  4.5  9.0  12.0</td>
<td>3.0  6.0  10.5  12.0</td>
</tr>
<tr>
<td>1600MHz</td>
<td>625ps</td>
<td>3.0  4.6  9.4  12.6</td>
<td>3.0  6.2  11.0  12.6</td>
</tr>
<tr>
<td>2000MHz</td>
<td>500ps</td>
<td>3.0  5.0  11.0  15.0</td>
<td>3.0  7.0  13.0  15.0</td>
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</table>

- Zero redundancy applied for four channels
  - Fixed frequency separation with a ratio of 1:3:2 or 2:3:1
Discussion with Ujihara-san, who is a famous eccentric feed designer

I will manage it with nested design if choosing 1:3:2 separation.

OK! you will!
Nested feed horn??

Mother horn covers lower frequency  +  Daughter horn for higher frequency

Nested feed horn for covering lower and higher frequency
Narrow down the candidates...

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- **Physical structure limitation of the feed horn**
- **LNA bandwidth limitation for the compact antenna 4-14GHz**
- **Float number Ambiguities**
- **Signal of Satellite in 11-13GHz**
Just small shifted…

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- **Red**: Physical limitation by the feed horn
- **Green**: LNA bandwidth for the compact antenna 4-14GHz
- **Yellow**: Float number Ambiguities
- **Blue**: RFI bandwidth from Satellite 11-13GHz
We decided Fixed quad-band channels

- 3.2GHz, 4.8GHz, 9.6GHz and 12.8GHz
- Center freq: 4.0, 5.6, 10.4 and 13.6GHz

Allocation of the fixed frequency channel of Gala-V.

We started the development!
The Gala-V feed horn, named “Iguana”.

- Mother feed (Colgate horn): ~3 – 7GHz
- Daughter feed (Multi-mode horn): ~9 – 15GHz
- HPBW ~ 10 degree for 34m antenna
- 2 linear polarization output

Preliminary beam pattern @ 13-Sep.

Image of Iguana feed
By Ujihara-san
Iguana to Kashima 34m

We replaces 5/10GHz rx to the Gala-V.

Don’t worry! S/X receivers are still remained!
The Prototype will be installed by next March.
RF front-end for 1.5m compact antenna

QARH 2-11GHz

LNF: 4-14GHz

BPF array for the interferences suppression
RF front-end plan for Kashima 34m

High band 9 - 15GHz

LNA ① → 4div → LNA ① → 4div → BPF array

Low band 3 - 7GHz

LNA ② → 4div → LNA ② → 4div → BPF array

LNF: 4-8GHz

LNF??: 10-15GHz

We need an LNA 10-15GHz!
Do you have any info??

BPF array for the interferences suppression

Synthesize high and low channels

To E/O
The sequence has an advantage in sampling!

In case of **12.8GHz** sampling

- All channels align in 6.4GHz band without any frequency conversions by PLOs and mixers.
- All four channels can sample at the same time!
New Gala-V sampler

- Prototype Model: ADX840
- Maximum 16Gsp* 3bit * 2ch
- 12.8Gsp, 6.4Gsp and 3.2Gsp
- 1600MHz output for Gala-V
- 1024MHz output for compatibility
- Four 10GbE outputs
- **Single sampler gets all 4bands*2pols!!!**

Old model ADX831
In case of **3.2GHz** sampling

- All channels are packed within 1.6GHz zone and are totally mixed ...
• But it is possible to make a VLBI even if bands are mixed!
• We called the technique, “DSAMS”!
DSAMS for 24hr “Mixed” S/X VLBI

Takefuji+, 2012
Bandwidth synthesis

- Delays in low band, high band are slightly small due to same feed horn and single fiber transmission, so we assume BWS is easy.

- Delay between low and high bands is bigger caused by different feed horn and LNA.

- So we need phase-cal injection before horns.
Phase-cal emission test (last week)

- Digital Phase-cal
- Broadband receiver

![Graph showing emission test results](image-url)

- Facing horns
- Reflecting from the wall
NICT’s ‘Galapagos VLBI System’
  targeting semi-compliant with VLBI2010

• Expecting particular/suitable evolution in limited condition.
• Every conventional S/X system may be possible to upgrade to the Gala-V system
• We wish strongly for making co-observation and collaboration with VLBI2010 antennas in the world.
Summary

Our decision:
• Fixed four bands: 3.2GHz 4.8GHz 9.6GHz 12.8GHz
• Bandwidth: 1024MHz to 1600MHz

Development:
• Iguana recursive feed horn.
• RF front end (LNAs, BPF for RFI, Optical transceiver)
• Backend (RF direct sampler, down converter for conventional compatibility)
Example of BWT function

- We have to take care of an ionospheric correction!
In case of 6.4GHz sampling

- 1\textsuperscript{st} and 2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} channel becomes adjacent after 6.4Gsps. Filter needed (HPF and LPF)
Maybe QARH will be replaced to...

The QARH covers 2-11GHz, But Gala-V needs to 15GHz