The Potential for a

Ka-band Worldwide VLBI Network

C. S. Jacobs


Overview

- Pros & Cons of Ka-band (32 GHz, 9mm)

- Ka-band antennas
  - Status of existing Ka-band antennas
  - potential future Ka-band antennas

- UV coverage simulations

- Feeds: S/X/Ka and X/Ka
Motivation for Ka-band (32 GHz/ 9mm)

- Astrometry, Geodesy and Deep Space navigation, have been at 3.6cm/8.4 GHz (X-band) with 2.3 GHz (S-band) plasma cals

**Ka-band (32 GHz / 9 mm) Advantages:**
- More *compact* sources which should lead to more *stable* positions!
- Higher Telemetry Rates: +5 to +8 dB
- Smaller, lighter RF spacecraft systems
- Avoid S-band *RFI* issues
- Ionosphere & solar plasma down 15X !! at 32 GHz (Ka-band) compared to 8 GHz thus observe closer to Sun & Galactic center

**Disadvantages of Higher radio frequencies:**
- More weather sensitive, higher system temp.
- Shorter coherence times
- Weaker sources, Many sources resolved
- Antenna Pointing more difficult
Ka-band: on the edge of the Radio Window

- O₂ line: 0.5 cm/ 60 GHz
- Water: 1.3 cm/ 22 GHz
- L-band: 19-24 cm
- W-band: 0.3 cm
- Ka-band: 0.9 cm
- X-band: 3.6 cm
- S-band: 13 cm

Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).

Visible light observable from Earth, with some atmospheric distortion.

Most of the infrared spectrum absorbed by atmospheric gases (best observed from space).

Radio waves observable from Earth.

Long-wavelength radio waves blocked.

Source Structure vs. Wavelength

S-band
2.3 GHz
13.6cm

X-band
8.6 GHz
3.6cm

K-band
24 GHz
1.2cm

Q-band
43 GHz
0.7cm

Ka-band
32 GHz
0.9cm

The sources become more compact

Image credit: P. Charlot et al, AJ, 139, 5, 2010
Positions differences from ‘core shift’

- wavelength dependent shift in radio centroid.
- **3.6cm to 9mm core shift:**
  - 100 μas in phase delay centroid?
  - <<100 μas in group delay centroid?  *(Porcas, AA, 505, 1, 2009)*
- shorter wavelength closer to Black hole and Optical: **Ka better than X-band**
X/Ka source catalog exists: 466 sources

DSN data, 200-300 μas accuracy. Weakens southward, No south cap.

Credit: Jacobs et al, Journees 2011, (poster, this meeting)
Jacobs et al, 20th EVGA, Bonn, Germany, 2011
Ka-band candidates: 498 sources identified

Ka candidate criteria: 200 mJy, 70% flux in unresolved X-band core
South polar cap is well covered, ready for observations.
Potential Ka-band VLBI Network

Map credit: maps.google.com
### Overview: Ka European VLBI Network

<table>
<thead>
<tr>
<th>Location</th>
<th>Country</th>
<th>Diameter</th>
<th>Bandwidth</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robledo</td>
<td>Spain</td>
<td>34-m</td>
<td>S/X/Ka</td>
<td>now</td>
</tr>
<tr>
<td>Cebreros</td>
<td>Spain</td>
<td>35-m</td>
<td>X/Ka</td>
<td>now</td>
</tr>
<tr>
<td>Effelsberg</td>
<td>Germany</td>
<td>100-m</td>
<td>Ka</td>
<td>now lin-pol</td>
</tr>
<tr>
<td>Wettzell</td>
<td>Germany</td>
<td>13-m</td>
<td>S/X/Ka</td>
<td>2012</td>
</tr>
</tbody>
</table>

**RAEGE sub-net**

<table>
<thead>
<tr>
<th>Location</th>
<th>Country</th>
<th>Diameter</th>
<th>Bandwidth</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yebes</td>
<td>Spain</td>
<td>13-m</td>
<td>S/X/Ka</td>
<td>2012</td>
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<tr>
<td>Santa Maria</td>
<td>Azores</td>
<td>13-m</td>
<td>S/X/Ka</td>
<td>2013</td>
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<tr>
<td>Flores</td>
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<td>13-m</td>
<td>S/X/Ka</td>
<td>2014</td>
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<tr>
<td>Canaries</td>
<td>Spain</td>
<td>13-m</td>
<td>S/X/Ka</td>
<td>2014</td>
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<tr>
<td>Yebes</td>
<td>Spain</td>
<td>40-m</td>
<td>S/X/Ka</td>
<td>2013/4</td>
</tr>
<tr>
<td>Kazan</td>
<td>Russia</td>
<td>12-m</td>
<td>S/X/Ka</td>
<td>TBD</td>
</tr>
<tr>
<td>Kislovodsk</td>
<td>Russia</td>
<td>12-m</td>
<td>S/X/Ka</td>
<td>TBD</td>
</tr>
</tbody>
</table>
Overview: Ka Pacific VLBI Network

**South Pacific sub-Net**
- Tidbinbilla, Australia 34-m X/Ka now
- Narrabri, Australia 6x22-m Ka now
- Mopra, Australia 22-m Ka now
- Parkes, Australia 12-m S/X/Ka TBD

**Auscope+NZ**
- Hobart, Australia 12-m S/X/Ka now/TBD
- Katherine, Australia 12-m S/X/Ka now/TBD
- Yaragadee, Australia 12-m S/X/Ka now/TBD
- Warkworth, New Zealand 12-m S/X/Ka now/TBD

**North Pacific Outriggers**
- Kashima, Japan 34-m Ka now
- Usuda, Japan 45-m S?/X/Ka 2018

**East Pacific outrigger** *(not in uv simulation)*
- Goldstone, CA, USA 34-m X/Ka now
AIPS simulated UV Coverage for European Sub-net

AIPS version 31Dec10, © Associated Universities, [http://www.aips.nrao.edu/](http://www.aips.nrao.edu/)
Snapshot Integration=1 min, interval=30 min, Bandwidth=500 MHz

Declination +75 deg

Declination +60 deg
AIPS simulated UV Coverage: South Pacific sub-net

Declination -75 deg

Declination -60 deg
AIPS simulated UV Coverage: Pacific

South Pacific sub-net

South Pacific sub-net + Japan

Declination -45 deg

Declination -30 deg
S/X/Ka Feed for TTW 13-meter

Twin Telescopes Wettzell (TTW)
IVS VLBI-2010 vision
Fast moving, 13.2-meter, Ring Focus
Estimated Ka fringe test spring 2012

Mirad S/X/Ka Feed for TTW
Drawing courtesy Gerhard Kronschnabl
RAEGE S/X/Ka Feed

Tri-band for S, X and Ka. Moderate bandwidth (<20%)
- S band  2.2 - 2.7 GHz
- X band  7.0 - 9.5 GHz
- Ka band  28.0 - 33.0 GHz

Return Losses <10 dB

Cryogenic cooled (70K)

Output waveguide
- S and X bands: waveguide to coaxial transitions
- Ka band circular waveguide

Dual-circular polarisation
- S and X bands: coaxial 180° and 90° hybrids
- Ka band: septum polarizer

Diameter 13-m, Az: 12 deg/s, El: 6 deg/s
X/Ka di-chroic feed designed for Patriot 12-meter
No S-band, thus no S/X backward compatibility

Credit: D.J. Hoppe & H. Reilly, JPL IPN Prog. Rept. 42-157, 2004
Conclusions

• Ka-band (32 GHz, 9mm)
  • Pros:
    • High Resolution to nearly Giga-lambda/nano-radian
    • S/X/Ka Feeds nearly ready for TTW/RAEGE 13-m
    • X/Ka catalog exists with nearly 500 sources
  • Cons:
    • Weather sensitive, higher Tsys requires >= 2 Gbps
    • status of many stations TBD
    • JPL Feed for 12-m Patriot is X/Ka thus no S/X

• UV coverage simulations
  • Excellent coverage for circumpolar sources
  • Potential for both North & South sub-Nets
First Ka-band Fringes outside the DSN: Effelsberg-DSS 55
DOY 223, source OT 081, 28 x 4MHz chan @2-bit, 448 Mbps

Thank you for your Attention. Questions?

Map credit: maps.google.com