# A POTENTIAL Ka-BAND (32 GHz) WORLDWIDE VLBI NETWORK

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ABSTRACT. Ka-band VLBI capability now exists, is under development or is being considered at 22 sites around the world. Thus, there is now an opportunity to create a worldwide Ka-band VLBI network. This paper will examine the potential for a cooperative network capable of high resolution imaging and astrometry. Initial fringe tests on a few individual baselines have been successful and more tests are planned. With baselines approaching a Giga-lambda, a Ka-band network would be able to probe source structure at the nano-radian (200 $\mu$as) level and thus gain insight into astrophysics of the most compact regions of emission in active galactic nuclei.

## 1. INTRODUCTION

There are 22 VLBI antennas worldwide that either have, are planning, or are considering Ka-band capability (Table 1). Ka-band is around 32 GHz or 9 mm wavelength. It is found between the 22 GHz water line and the 60 GHz $O_2$ line. At Ka-band sources tend to be more core dominated because the extended structure in the jets tends to fade away with increasing frequency.

*Advantages of Ka*: There are several advantages of Ka-band. The short 9 mm wavelength and long baselines approaching a Giga-$\lambda$ allow for resolution approaching 200 $\mu$as. The sources are more compact than at X-band which should reduce source structure effects and core shifts. Ka-band allows for higher telemetry rates for spacecraft communications by +5 to +8 dB as well as smaller lighter RF spacecraft systems. Ka-band avoids S-band RFI issues. Ionosphere and solar plasma effects are reduced by a factor of 15 compared to X-band, thus allowing observations closer to the Sun or the Galactic center.

*Disadvantages of Ka:* Because Ka-band is near the 22-GHz water line, Ka-band is more weather sensitive and has higher system temperatures than comparable systems at X-band. Because Ka-band has a shorter wavelength than X-band, coherence times are shorter thus limiting the potential for longer integrations on source. Some sources are weaker or resolved. Antenna pointing is more difficult. The net effect is to reduce system sensitivity. Our intent is to compensate by increasing data rates.

*X/Ka-band radio catalog:* A catalog of ∼470 Ka-band sources already exists. Based on comparisons to the S/X-based ICRF2 (Ma et al., 2009), Ka-band accuracy is 200 to 300 $\mu$as (Jacobs et al., 2011). The south polar cap is not yet covered, but a pilot project is now underway using 144 of the 498 candidates identified by Sotuela et al. (2011). So sufficient sources exist to provide geodetic reference sources and calibrators for phase referencing.

## 2. NETWORK GEOMETRY AND UV COVERAGE

How strong is the potential for imaging? Using AIPS software, we simulated the set of projected baseline lengths generated as the Earth rotates (uv coverage). The European sub-net (1st 11 stations of Table 1) covers out to 600 M$\lambda$ and gives excellent coverage for circumpolar sources (Figure 2a). Likewise, the south Pacific sub-net has good circumpolar coverage to 500 M$\lambda$. Adding Japanese "outriggers" gives ∼G$\lambda$ North-South resolution, but with a sacrifice in the uniformity of coverage (Figure 2b).


Figure 1: Ka-band Station Distribution. Note clusters in Europe and Australia. *Credit: Google maps*

In summary, there is potential for imaging at the few 100 $\mu$as level which corresponds to the inner few parsecs of a typical active galactic nucleus where the most energetic processes are thought to occur.

## 3. Ka-BAND FEEDS

Ka-band capable feeds are a key element required for a functioning Ka network. NASA's Deep Space Network (DSN) has had X/Ka feeds for over a decade in its 34-m antennas (e.g. Chen et al., 1993 and 1996; Stanton et al., 2001). More recently, several designs have appeared for 12-m class antennas intended for geodesy in the IVS-2010 era. Hoppe & Reilly (2004) designed an X/Ka feed for the (then) Patriot 12-m antenna. Twin Telescopes Wettzell (TTW) is designing an S/X/Ka feed (Göldi, 2009). The RAEGE project is also designing an S/X/Ka feed. Thus there are sufficient feed designs to equip antennas at Ka-band. We have achieved our first Ka-band fringes outside the DSN on a baseline from

| marker | Station | Location | Size (m) | bands | date |
|---|---|---|---|---|---|
| A | Robledo | Spain | 34 | S/X/Ka | now |
| B | Cebreros | Spain | 35 | X/Ka | now |
| G | Effelsberg | Germany | 100 | Ka | now |
| H | Wettzell | Germany | 13 | S/X/Ka | 2012 |
| | RAEGE Net | | | | |
| C | Yebes | Spain | 13 | S/X/Ka | 2012 |
| F | Flores | Azores | 13 | S/X/Ka | 2014 |
| E | Santa Maria | Azores | 13 | S/X/Ka | 2013 |
| D | Canaries | Canaries | 13 | S/X/Ka | 2014 |
| C | Yebes | Spain | 40 | S/X/Ka | 2013/4 |
| | Russian Net | | | | |
| I | Kazan | Russia | 12 | S/X/Ka | TBD |
| J | Kislovodsk | Russia | 12 | S/X/Ka | TBD |
| | S. Pacific Net | | | | |
| K | Tidbinbilla | Australia | 34 | X/Ka | now |
| L | Narrabri | Australia | 22 | Ka | now |
| M | Mopra | Australia | 22 | Ka | now |
| N | Parkes | Australia | 12 | S/X/Ka | TBD |
| O | Hobart | Tasmania | 12 | S/X/Ka | TBD |
| P | Katherine | Australia | 12 | S/X/Ka | TBD |
| Q | Yaragadee | Australia | 12 | S/X/Ka | TBD |
| R | Warkworth | New Zealand | 12 | S/X/Ka | TBD |
| | N. Pacific Net | | | | |
| S | Kashima | Japan | 34 | Ka | now |
| T | Usuda | Japan | 45 | X/Ka | 2018 |
| | E. Pacific | | | | |
| U | Goldstone | U.S.A. | 34 | X/Ka | now |

Table 1: Status of existing and potential Ka-band stations

DSS-55 to Effelsberg on day-of-year 223 of 2011 with source OT 081 recording at 448 Mbps.

## 4. CONCLUSIONS

Ka-band (32 GHz, 9 mm) Very Long Baseline Interferometric (VLBI) global networking is feasible within the next few years. Ka-band VLBI astrometry from NASA's Deep Space Network has already developed a catalog of observable sources with highly accurate positions. Now, a number of antennas worldwide are planning or are considering adding Ka-band VLBI capability. Thus, there is now an opportunity to create a worldwide Ka-band network capable of high resolution imaging and astrometry. With baselines approaching a Giga-lambda, a Ka-band network would be able to probe source structure at the nano-radian (200 $\mu$as) level and thus gain insight into the astrophysics of the most compact regions of emission in active galactic nuclei. We have discussed the advantages of Ka-band, shown $\sim$470 known sources and $\sim$500 candidate sources, simulated uv coverage, and discussed potential RF feeds. First Ka fringes have been demonstrated! All these things demonstrate that a worldwide Ka-band network is feasible within the next few years!

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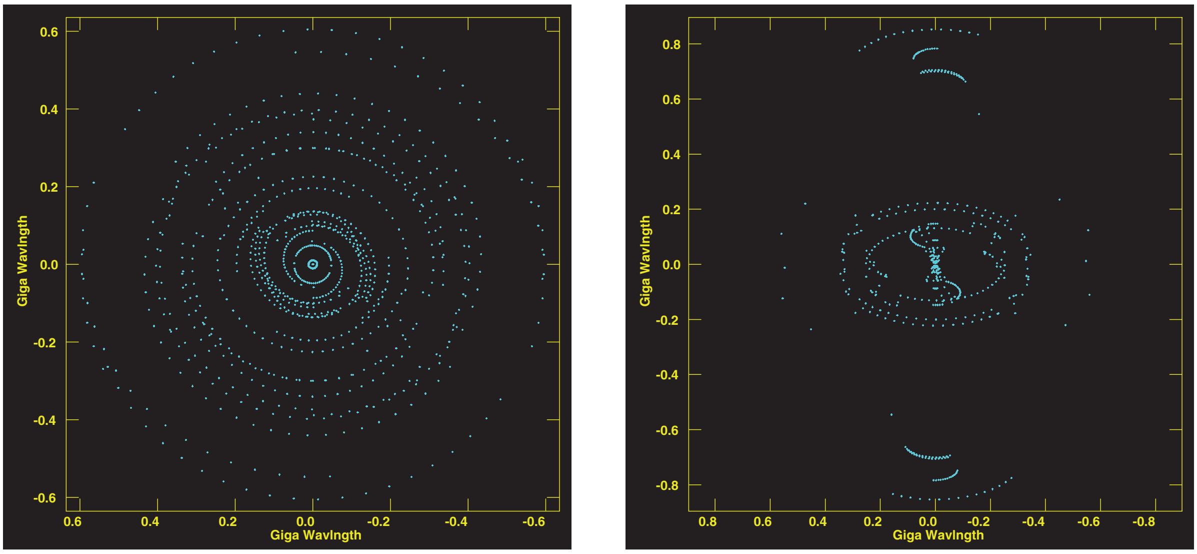


a. European network: source at Dec +75°.  b. S. Pacific net + Japan outrigger: Dec −30°

Figure 2: Ka-band Network UV coverage examples.

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