The Potential for a Ka-band (32 GHz) Worldwide VLBI Network

C. Jacobs[1], U. Bach[6], F. Colomer[7], C. Garcia-Miro[2], J. Gomez-Gonzalez[7], S. Gulyaev[9], S. Horiuchi[3], R. Ichikawa[12], A. Kraus[6], G. Kronschnabl[5], J.A. Lopez-Fernandez[7], J. Lovell[8], W. Majid[1], T. Natusch[9], A. Neidhardt[4], C. Phillips[13], R. Porcas[6], A. Romero-Wolf[1], L. Saldana[14], U. Schreiber[5], I. Sotuela[2], H. Takeuchi[11], J. Trinh[1], A. Tzioumis[13], P. de Vicente[7], V. Zharov[10]

(1) Jet Propulsion Laboratory, California Institute of Technology/NASA (2) Madrid Deep Space Communications Complex/NASA, INSA, Madrid, Spain, (3) Canberra Deep Space Communications Complex/NASA, C.S.I.R.O., Canberra, Australia (4) Technische Universitaet Muenchen, Germany (5) Bundesamt fuer Kartographie und Geodaesie, Bad Koetzting, Germany (6) Max-Planck-Institut fuer Radioastronomie, Bonn, Germany (7) Instituto Geografico Nacional, Madrid, Spain (8) University of Tasmania, Hobart, Australia (9) Institute for Radio Astronomy and Space Research, Auckland University of Technology, Auckland, New Zealand (10) Sternberg State Astronomical Institute, Moscow, Russia (11) ISAS/JAXA, Sagamihara, Japan (12) Kashima Space Research Center, NICT, Kashima, Japan (13) CSIRO, Australia (14) ITT Exelis, Monrovia, CA

Abstract: Ka-band (32 GHz, 9mm) Very Long Baseline Interferometric (VLBI) networking is now begun and has tremendous potential for expansion over 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, several 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 with potential for 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 µas) level (~100X better than Hubble) and thus gain insight into the astrophysics of the most compact regions of emission in active galactic nuclei. We discuss the advantages of Ka-band, show known & candidate sources, simulate projected baseline ("uv") coverage, and discuss potential radio frequency feeds. The combination of all these elements demonstrates that a worldwide Ka-band network is feasible within the next few years!

Fig. 1 Potential Ka-band Network using existing, planned, and proposed sites.

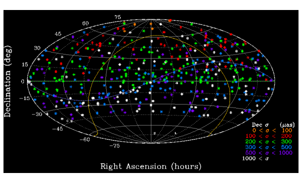


Fig. 5: Existing X/Ka radio catalog of 466 sources (Jacobs et al, 20th EVGA, 2011)

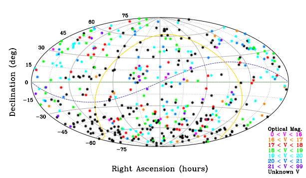


Fig. 6: X/Ka 498 candidate sources (Sotuela et al, GREAT-ESF, 2011)

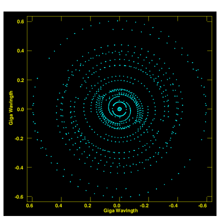


Fig. 7a. Ka Euro sub-Net, Declination +75 deg.

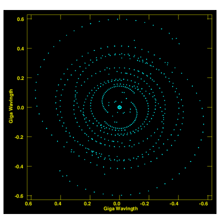


Fig. 7b. Ka Euro sub-Net, Declination +60 deg.

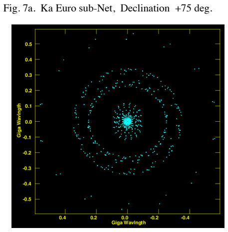


Fig. 7c. Ka South Pacific sub-Net, -75 deg Dec.

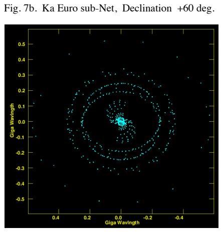


Fig. 7d. Ka South Pacific sub-Net, -60 deg Dec.

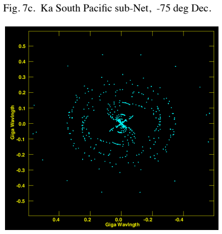
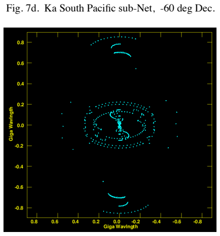


Fig. 7e. Ka South Pacific sub-Net, -45 deg Dec.



7f. Ka South+North Pacific sub-Nets, -30 deg Dec

Table 1. Ka-band European VLBI sub-net

Robledo,	Spain	34-m	S/X/Ka	now
Cebreros,	Spain	34-m	X/Ka	now
Effelsberg,	Germany	100-m	Ka	now Xpol
Wettzell,	Germany	13-m	S/X/Ka	2012
Yebes,	Spain	13-m	S/X/Ka	2012
Canaries,	Spain	13-m	S/X/Ka	2013
Santa Maria,	Azores	13-m	S/X/Ka	2014
Flores,	Azores	13-m	S/X/Ka	2014
Kazan,	Russia	12-m	S/X/Ka	TBD
Kislovodsk,	Russia	12-m	S/X/Ka	TBD

UV simulations: Using AIPS software (AU/NSF) we simulated the set of projected baseline lengths generated as the Earth rotates ("uv coverage"). The Euro sub-net can cover out to 600 Mega-lambda, the south Pacific sub-net to ~500 Mega-lambda, with both arrays having potential for almost a Giga-lambda if outriggers in the U.S. and/or Japan are added.

- Fig 7a shows uv coverage for the Euro net (Tab. 1) for a circumpolar sources at Dec=+75
- Fig 7b shows the same network for a slightly lower source at Dec=+60.

- Fig 7c,d shows the S. Pacific sub-net for circumpolar sources at Dec= -75 and -60 deg.
- Fig 7e shows the changes in coverage as one moves toward the equator.
- Fig 7f shows the effect of adding Japanese stations which extend North-South coverage to ~800 M-lambda.

In summary, there is potential for imaging at the few 100 µas level.

Table 2. Ka-band 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

Table 2b. Ka-band North Pacific Outriggers

Kashima,	Japan	34-m	Ka	now
Usuda,	Japan	45-m	S/X/Ka	2018

Table 2c. E.Pacific outrigger (not simulated)

Goldstone,	CA, USA	34-m	X/Ka	now

Introduction:

There are 21 VLBI antennas worldwide that either have, are planning, or are considering Ka-band capability (Fig. 1 and Tables 1, 2). Ka-band is ~32 GHz or 9mm wavelength. It is found between the 22 GHz water line and the 60 GHz O_2 line (Fig. 2). At Ka-band sources tend to be more core dominated because the extended structure in the jets tends to fade away with increasing frequency (Figs. 3 & 4).

Advantages of Ka-band:

- More compact, stable sources (Fig. 4)
- Higher Telemetry rates by +5 to +8 dB
- Smaller lighter RF spacecraft systems
- Avoids S-band RF interference issues
- Ionosphere & solar plasma down by 15X.

Disadvantages of Ka-band:

- More weather sensitive
- Shorter coherence times
- Weaker sources, many resolved

- Antenna pointing is more difficult, but Rochblatt et al (2007) have demonstrated Ka-band pointing for large 34-m antennas.

- Combined effect is lower sensitivity, but advances in recording technology are rapidly compensating (e.g. Whitney & Cappallo, Mark-6, this meeting).

X/Ka-band radio catalog:.

- Catalog of ~470 Ka sources exists (Fig. 5) Accuracy is 200 to 300 µas compared to the S/X-based ICRF2 (Garcia-Miro et al, this meeting, Jacobs et al, EVGA, 2011)

- South polar cap not yet covered, but pilot project underway (Horiuchi et al, this meeting) using candidates (Fig. 6) identified by Sotuela et al (GREAT-ESF, 2011).

Feeds for VLBI-2010 dishes:

- The DSN has had X/Ka feeds for several years 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 (Fig. 8) for the (then) Patriot 12-m antenna.
- Twin Telescopes Wettzell (TTW) is designing (Goldi, 2009) an S/X/Ka feed (Fig. 9).
- The RAEGE project is also designing an S/X/Ka feed (Fig. 10a,b) (Tercero and Lopez-Perez et al, both this meeting)

First Ka fringes augmenting the DSN!

- In 2011, we achieved 1st Ka-band fringes to extend the Ka-net outside DSN (Fig. 11).
- Ka fringe tests to TTW and RAEGE are being planned for the next year or so.

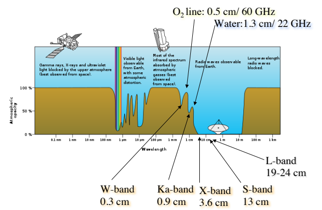


Fig. 2: Frequencies in relation to the Radio Window (credit: NASA)

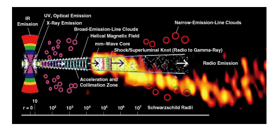


Fig. 3: Schematic of quasar. (Marscher, 2006, Krichbaum, 1999, Wehrle, 2010)

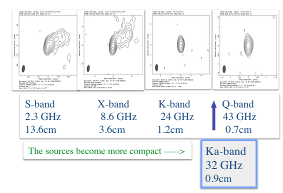


Fig. 4: Source structure & compactness vs. wavelength (Charlot et al, AJ, 2010)

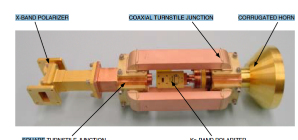


Fig. 8. X/Ka di-chroic feed designed for Patriot 12-m (Hoppe & Reilly, 2004).

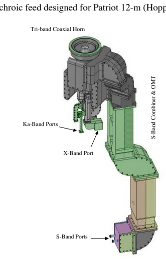
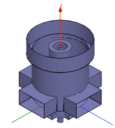


Fig. 9. S/X/Ka tri-chroic feed. Designed by Mirad for 13.2-m Twin Telescope Wettzell (Goldi, 2009).



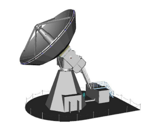


Fig. 10a. RAEGE S/ X/Ka tri-chroic feed 10b. 13.2-m high speed, ring focus antenna

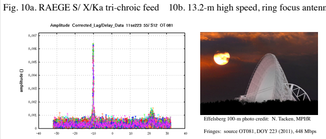


Fig. 11. First Ka fringes outside DSN: Effelsberg-DSS-54 (Jacobs et al 2011).

Conclusions: Ka-band (32 GHz, 9mm) 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 µas) level (~100X better than Hubble) and thus gain insight into the astrophysics of the most compact regions of emission in active galactic nuclei. We discuss the advantages of Ka-band, show known & candidate sources, simulate "uv" coverage, and discuss 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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