A STUDY OF VLBI2010 POTENTIAL FOR SOURCE STRUCTURE CORRECTIONS

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ABSTRACT. In October 2003, the International VLBI Service for Geodesy and Astrometry (IVS) installed Working Group 3 'VLBI2010' to examine current and future requirements for geodetic/astrometric VLBI including all components from antennas to analysis, and to create recommendations for a new generation of VLBI systems. Some important recommendations include: the use of larger networks; the use of smaller faster slewing antennas; the use of very high data rates; and, the use of multiple (e.g. 4) widely spaced bands to resolve RF phase ambiguities. When taken together, these recommendations result in a many-fold increase in the number of observations per session. UV coverage improves to the point where precise VLBI images of the ICRF sources can be constructed on a daily basis directly from the geodetic observations, therefore enabling source structure corrections to be calculated. Simulations are currently underway to evaluate the potential of this approach.

1. WHY ARE SOURCE STRUCTURE CORRECTIONS NEEDED?

The ideal radio source for reference frame definition has no structure or apparent variation in position. Real sources, on the other hand, typically have measurable structure, and to make matters worse, structure that often varies noticeably with time. Structure itself is manifest as a variation in interferometer delay, phase and amplitude with respect to baseline geometry. When these vary with time, this is usually manifest as apparent motion of the source.

2. THE IMPACT OF IVS'S VLBI2010

A strategy for mitigating the reference frame degradation due to source structure is to actively monitor that structure and correct for it. This has not been done routinely in the past because current operational geodetic/astrometric schedules do not include enough source observations to allow the creation of high quality images.

In 2003, the International VLBI Service for Astrometry and Geodesy (IVS) began a process of renewal. A working group was struck, called VLBI2010, to fully define by the year 2010, a next generation VLBI system with major goals of achieving 1 mm position accuracy and continuous observations.

The anticipated VLBI2010 operating modes resulting from rapid slewing antennas, higher data rates and broadband operation enable the possibility of a manifold increase in the number of observations per session. This opens up the practical possibility of routinely generating active source structure corrections from each operational geodetic/astrometric observing session.

3. GENERATING SOURCE STRUCTURE CORRECTIONS

Step1. The first step in generating structure corrections involves making images of the source. Based on the resulting maps, it is then possible to calculate, on a band-by-band basis, structure corrections for each input observation. The quality of the maps is dependent on two factors: UV coverage and signalto-noise ratio (SNR). UV coverage is a measure of the number of different geometries from which the source is observed. The new tactics being considered for VLBI2010, including larger global networks and faster slewing antennas, promise a quantum improvement in UV coverage. The high imaging potential of the VLBI2010 observing modes has been demonstrated through simulations. Although noise has not yet been included in the analysis, this extension of the simulations is expected in the near future.

Step2. This step involves aligning the map centres in different bands. VLBI observations are typically carried out in a number of different frequency bands, e.g. current geodetic VLBI operations use both S-band and X-band. In VLBI2010 observing modes, it is anticipated that four or more bands, spread over a frequency range of 2-15 GHz, will be used to both remove the effect of the ionosphere, and enable the use of the VLBI phase delays, which are about an order of magnitude more precise than currently used group delays. Since the generation of the maps requires the use of phase closure data, which, by its nature, has had all absolute position information removed, the images in the different bands need to be aligned after the the fact.

Fortunately, the output group and phase delays contain sufficient information to simultaneously resolve phase ambiguities and align the map centres. The ability to do this is dependent on both the frequency of the band and the number of observations of the source. Simulations indicate that in almost all cases, even for the lowest frequency band, it is possible to align the bands to better than about 20 uas (at the 1 sigma level).

Step3. The final step in applying source structure corrections is to identify a reference point in the map. Without corrections, this is naturally placed at the centroid of illumination. Unfortunately, the centroid is typically not fixed over time.

What would be better for geodesy/astrometry would be to associate some feature of the map with a positionally invariant physical feature of the source, typically the black hole at its core. The problem is that the majority of radio emission from the source is generated by dynamic jets emanating from the core, but not the core itself. Some success has been achieved by modeling the core-jet nature of the source as a point plus elliptic component [Fomalant].

Another tantalizing possibility presents itself with the multiband VLBI2010 data. The jet is usually viewed nearly end-on, and the image represents the point at with the jet becomes optically thick at that frequency. The higher the frequency, the closer the image is to the core. It may be possible to use the series of multi-frequency images enabled by the VLBI2010 operating modes to point towards (and perhaps infer) the position of the positionally invariant core of the quasar.

4. CONCLUSIONS

Although more simulation work needs to be done, this work has shown that anticipated VLBI2010 operating modes are likely to enable the implementation of effective source structure corrections making it possible to better associate VLBI observations with the positionally invariant point in each observed radio source. This is important for a number of reasons:

- It will improve the accuracy and stability of the ICRF.
- It will, in turn, improve the accuracy of EOP and the ITRF.
- It will help enable the "broadband delay" technique designed to resolve RF phase ambiguities and hence lead to about an order of magnitude improvement in the VLBI delay observable precision.
- It will result in the first routine production of inter-band image alignment, providing important new information about quasar jet structure and dynamics.
- It will provide an interesting astronomical data base of compact radio sources imaged on a daily basis.

5. REFERENCES

Fomalant, E. “VLBA Phase Referencing for Astrometric Use”. In: International VLBI Service for geodesy and astrometry 2006 General Meeting Proceedings, pp 307-315.