ASTROMETRY VLBI IN SPACE (AVS)

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1. MISSION GOALS

This paper describes a proposal for a new space radio astronomy mission for astrometry which uses very-long-baseline interferometry (VLBI) called Astrometry VLBI in Space (AVS). The ultimate goals of AVS are to improve the accuracy of radio astrometry measurements to the microarcsec-

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ond level in one epoch of measurements and to improve the accuracy of the transformation between the inertial radio and optical coordinate reference frames. The scientific objectives of the mission cover a few categories of astrometry tasks such as astrometry of the solar system, reference frames ties, tests of general relativity and cosmology (for references see Lowe and Treuhaft,1994, Russell et al.,1992, Eubanks et al.,1994).

2. MISSION CONCEPT

Current ground-based VLBI radio astrometry angular accuracy is primarily limited by atmospheric propagation effects and by the length of the longest attainable Earth baselines ($\sim$ 10000 km). Efforts to tie the radio and optical frames with observations of radio stars will be limited to the few-tenths of a milliarcsecond level by the unmodeled angular difference between the optical and radio centers of emission.

The above astrometric limitations can be circumvented if the radio interferometer is placed in space. It is possible to establish a unified Celestial Reference Frame and to tie an inertial Radio Reference Frame, an Optical Reference Frame, and a Geocentric-Equatorial Reference Frame with unprecedented accuracy.

A basic element of the proposed mission is a space-based radio interferometer composed of two free-flying antennas operating simultaneously with a 70m ground-based telescope at 8.4, 22.2, 32, 43 GHz. The space antennas will be located in orbit such that they will be visible to each other most of the time. A microwave (or laser) link will be established between the Space Radio Telescopes (SRTs) to provide a direct measurement of the radio interferometer baseline length, and synchronization of the SRTs' local oscillators and clocks. Along with radio interferometry equipment, each spacecraft will carry an optical beacon and optical (CCD) astrometry camera. The camera will determine the position of the optical beacon (the spacecraft with the radio telescope) relative to the optical reference stars (Figure 1).

The advantages of such a configuration are (see Alekseev, 1981,1993):

i) Such system excludes the limitations of ground-based radio astrometry due to atmospheric turbulence and refraction, Earth's motions, impossibility to view the entire sky with a single instrument;

ii) The baseline of the space-based radio interferometer (and, accordingly, its angular resolution) will not be limited by the Earth's diameter;

iii) Optical astrometry devices will provide the orientation for the radio interferometer baseline relative to the optical reference frame, thus the coordinates of the radio sources will be determined directly in the optical reference frame;

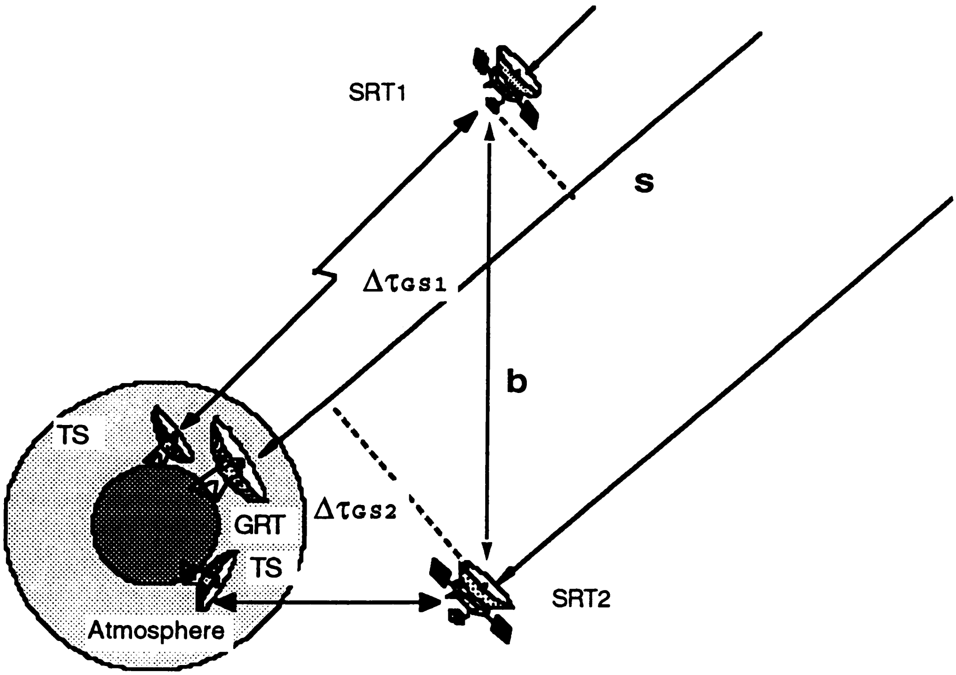

Figure 1. **AVS mission configuration**

iv) Direct determination of the baseline length and synchronization of the SRTs' local oscillators and clocks by a microwave link established between two spacecraft can, in principle, allow the use of a fringe phase for angular measurements, as in connected-element interferometry, instead of the group delay as used in Earth-based VLBI.

Astrometric VLBI observations by this system can provide a relative time group delay $\Delta\tau_{12}$ (main value used in VLBI astrometry measurement) between two space radio telescopes, and, accordingly, the coordinates of the radio sources as determined from the equation $c\Delta\tau_{12} = (\vec{b}\ \vec{s})$, which will not include an atmospheric impact (τ_{ATM}) and instrumental time delays in GRT equipment (τ_{ID}):

$$\Delta\tau_{GS1} - \Delta\tau_{GS2} = (\tau_{SRT1} - \tau_{GRT} - \tau_{ATM} - \tau_{ID}) - (\tau_{SRT2} - \tau_{GRT} - \tau_{ATM} - \tau_{ID}) = \Delta\tau_{12}$$

At the same time, simultaneous observations of a space radio interferometer combined with relatively small antennas with diameter d_{SRT} and a large ground-based radio telescope with diameter D_{GRT} will increase the signal-to-noise ratio (SNR) and, accordingly, decrease the stochastic error of radio astrometry measurements with a space-based radio interferometer:

$$\sigma(\Delta\tau_{12}) = \sqrt{\sigma^2(\Delta\tau_{GS1}) + \sigma^2(\Delta\tau_{GS2})} \sim \sqrt{2}(D_{GRT} \cdot d_{SRT})^{-1}$$

An orbiting interferometer operated at $\lambda \sim 1$ cm with a baseline between two 4-m diameter space radio telescopes $|\overrightarrow{b}| \sim 50.000$ km observing with a 70m ground-based telescope with system parameters of both space and ground telescope: Tsys= 50 K, T=300 sec, $\Delta\nu$ =128 MHz can provide angular measurements with an accuracy better than 10 and 100 microarcsec for the sources with flux density 1Jy and 0.1 Jy, respectively.

3. MISSION IMPLEMENTATION

This proposal could be implemented under the NASA category of "Midex Missions" (cost ~\$100 Mln). In order to meet this requirement, the mission design should be based on an existing (or feasible in near future) technology and existing supporting infrastructure. In order to keep the cost of this mission low, the space-based antennas should be small, and non deployable. If the SRTs will be launched in a geostationary orbit, the baseline for a space-based radio interferometer can be as long as 50,000-70,000 km. Two 4-m class non-deployable space antennas can be launched simultaneously by the Russian Proton or French Arian-5 boosters. The effectiveness (scientific return) of the proposed mission crucially depends on the support of large ground-based radio telescopes such as the 70m DSN antennas, the Effelsberg 100m radio telescope, the VLA phase array and the newly-developed Green Bank 100m telescope. VLBI observations are now (or will be) routinely provided by these radio telescopes at frequencies as high as 43 GHz.

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