RADIOINTERFEROMETRIC POLAR MOTION DETERMINATION USING A VERY LONG NORTH-SOUTH BASELINE

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ABSTRACT. The first high accuracy VLBI measurements with the Hartebeesthoek Radio Astronomy Observatory (HartRAO) at the southern end of the African tectonic plate were made possible at the beginning of 1986 through the loan of a MARK III DAT to HartRAO by the US National Geodetic Survey. Six twenty-four hour experiments spread over thirty-three days were used to precisely determine the HartRAO station position and to measure baseline lengths to Europe and North America. Interleaved between these multi-station experiments, a single baseline from Wettzell to HartRAO was used for two hours on a daily basis in order to measure pole positions. The formal errors of the x and y pole component determinations for each day are about ±2 mas and ±1 mas respectively, but an offset of about 6 mas from the IRIS values remains to be investigated.

1. INTRODUCTION

At the beginning of December 1985 a complete MARK III Data Acquisition Terminal (DAT) was sent on loan to the Hartebeesthoek Radio Astronomy Observatory (HartRAO) from the National Geodetic Survey (NGS), National Oceanographic and Atmospheric Administration of the U.S. Department of Commerce. In addition a concentric dual frequency feed and receiver assembly was provided by Haystack Observatory. The motivation for this experiment, despite the considerable logistic difficulties, was strongly supported by the recent acquisition of a hydrogen maser frequency standard by HartRAO which is essential for MARK III measurements.

The whole MARK III project included two groups of experiments. The first consisted of six 24 hour sessions using four stations while the second group contained twenty-seven two hour sessions using two stations. Both sub-projects will be described in more detail below.

2. MULTISTATION EXPERIMENTS

In January and February 1986 four experiments of 24 hour duration were carried out including the Westford Observatory in Massachusetts (USA),

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the Richmond Station in Florida (USA), the Wettzell Fundamental Station in Bavaria (FRG) and HartRAO. In two additional experiments Wettzell was replaced by Onsala Space Observatory (Sweden) in order to distribute the observational workload. The observing schedules for these six experiments were prepared by the NGS VLBI group. The same 14 radio sources were used in all six sessions covering a range of -29 to +39 degrees in declination.

Except for the first multi-station experiment which was correlated at the Haystack Observatory MARK III processor near Boston (USA), all tapes were correlated at the Max-Planck-Institute for Radio Astronomy (MPIfR) in Bonn (FRG). One of the authors, A Nothnagel, was given the opportunity to analyse the data with the MARK III Data Analysis System (CALC/SOLVE) at the Geodetic Institute of the University of Bonn.

All six sessions were processed in separate least square fits. The coordinates of the three base stations in the northern hemisphere were fixed since they have been determined by a large number of previous experiments. The respective earth orientation parameters of the IRIS network determinations as given in the regular IRIS Bulletin A were adopted.

The extreme length of the baselines, especially of those to North America, has a strong impact on the achievable accuracy since many observations have low elevations and are therefore contaminated by atmospheric effects. In order to reduce these effects all observations below an elevation cut-off of 15 degrees were rejected. The initial computations show acceptable repeatability in both baseline length and station coordinate determinations between the six multi-station experiments.
The computed weighted means of the baseline lengths are:

Wettzell - HartRAO	7832 322.45 m	±0.05
Westford - HartRAO	10658 658.38 m	±0.06
Richmond - HartRAO	10814 591.33 m	±0.06

with the weighted mean of the HartRAO station coordinates being:

	X	Y	Z
HartRAO	5085444.23	2668262.37	-2768697.05

3. DAILY EXPERIMENTS

3.1. OBSERVATIONS

In addition to the multi-station experiments twenty-seven short dual station experiments were scheduled for Wettzell station and HartRAO. These daily measurements in between the multi-station experiments were initiated by the Bonn Geodetic VLBI group with the aim of investigating possible short term variations in the polar wobble. The 1986 HartRAO MARK III experiment was the first in which both stations in a very long north-south baseline were equipped with wide band recording systems to determine accurate pole positions. These optimum conditions were ideal

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for intensive short time scale monitoring. Using a single north-south baseline, the measurements are sensitive to the two pole coordinates x_p, y_p but are insensitive to UT1 - UTC. The sensitivity increases with increasing baseline length and simulations predicted good results even with observing times as short as two hours.

In principle, the determination of the orientation of the earth's spin axis requires two planes to intersect in the axis. These two planes can be formed by observing equatorial sources with a ninety degree hour angle difference. In VLBI this simple approach is rendered more complex by the fact that in addition to x_p and y_p, at least one clock offset and one clock drift rate parameter have to be estimated for each experiment which leads to inherent but undesired correlations between these parameters.

In the least square fit the delay coefficients of the observation equations for the parameters to be estimated are:

clock offset: 1

clock rate: t_i

x_p: $1/c * (b_x * \sin(\delta) - b_z * \cos(\delta) * \cos(h_s))$

y_p: $1/c * (b_y * \sin(\delta) - b_z * \cos(\delta) * \sin(h_s))$

where
t_i = time of observation
δ = declination of source
h_s = Greenwich hour angle of source
c = velocity of light
b_x, b_y, b_z = baseline components

De-coupling of the pole coordinates and the clock parameters can only be achieved by observing sources with different hour angles and declinations. In the case of the HartRAO - Wettzell baseline the z - component is about eight and five times larger than the x - and y - component, respectively. Therefore the terms with b_z dominate the behaviour of the coefficients. Owing to the limited mutual visibility of sources and to avoid low elevation observations the declinations are restricted to the range -30 to +42 degrees and consequently the $\cos(\delta)$ terms vary only between 0.8 and 1.0 . Therefore, only changes in the Greenwich hour angle of the source can be used for de-correlation. In our case the Greenwich hour angle can vary from -80 to +50 degrees. This is an advantageous range for y_p since $\sin(h_s)$ has values from -0.98 to +0.72 and thus reduces the correlation between y_p and the clock offset to about -0.4 . On the other hand the $\cos(h_s)$ values range from 0.17 to 1.0 and never become negative. For this reason de-correlation between x_p and the clock offset can only be marginal.

In order to arrive at an optimized schedule, a compromise between the conflicting constraints was found by comparing the covariance matrices of a set of different possible schedules. Generally the same sidereal time in the morning was used to observe a set of 4 radio sources in a repeated sequence. Eleven observations were chosen to fit on two MARK III VLBI tapes per station per session which were recorded in about 100 minutes. Owing to other commitments of the Wettzell observatory some of the sessions had to take place in the evening. Therefore a second set of radio sources on the evening sky, different from the previous one, had to be employed. However, this fact makes it possible to compare results achieved with different schedules.

3.2. DATA ANALYSIS

Preliminary pole positions of these experiments were calculated with the MARK III Data Analysis System implemented at the Bonn Geodetic Institute. After these initial computations the data were transferred to a copy of the Bonn VLBI Software System (BVSS) implemented at HartRAO in order to make use of the higher flexibility of this single baseline program system. All sessions were recomputed with BVSS using the same input, corrections and weighting as with CALC/SOLVE. The compatibility of both software systems could be verified to an RMS difference of 1.1 mas in x_p and 0.4 mas in y_p with a bias of +0.8 mas and +0.1 mas, respectively.

In the least squares fits of twenty-three successful experiments the station coordinates of the two telescopes and the radio source coordinates were held fixed solving only for the two polar motion components x_p, y_p , and the offset and rate between the two station clocks. Higher order clock terms were neglected in these short observing periods. The IRIS values for UT1 - UTC, measured every five days, were introduced as the third earth orientation parameter.

3.3. RESULTS

Comparing the results of single sessions with interpolated IRIS pole positions for the respective epoch show average discrepancies of about -5.4 mas in x_p and +4.5 mas in y_p. However, our daily pole positions clearly follow the trend of the IRIS pole. The scatter of the offset is within the standard deviations and does not diverge over the full observation period of thirty-one days (Fig. 1). The standard deviations of x_p and y_p are about ±2 mas and ±1 mas, respectively. The weighting of the observations was chosen such that the quotient of the variances à posteriori divided by the variances à priori was close to one.

Considering the results of the morning and the evening experiments separately reveals a significant bias in the x-pole-coordinates of the evening experiments while their y-pole-coordinates seem to be unbiased. Owing to the different observing schedules used the correlations between clock offset and x_p are larger in the evening experiments (0.95) and in addition a considerable correlation between the clock offset and y_p of 0.8 appeared, which consequently leads to a correlation of 0.8 between x_p and y_p. Thus the results of the evening experiments can be regarded as less reliable even though their standard deviations seem to suggest otherwise.

In order to eliminate the existing offset various attempts have been made. One possible error source was the inaccurate nutation model for which Herring et al. [1] have calculated corrections.

The corrections for the 365.3 and 182.6 day periods were introduced and all sessions were re-calculated with the improved nutation model. This measure did not eliminate the offset but increased the discrepancy in y_p to +6.0 mas while the offset in x_p was decreased marginally to -4.6 mas.

A second source of uncertainty was suspected in the HartRAO station coordinates. Test calculations verified that the HartRAO x- coordinate would have to be shifted by -18 cm while the y - coordinate would need to be shifted by -20 cm to compensate for the -4.6 and 6.0 mas offset, respectively.

For the x - coordinate such a shift is not unreasonable since the results of the HartRAO x - coordinate in the multi-baseline fits were scattered about 20 cm about the mean and the baseline lengths are almost invariant to small changes in the HartRAO x - coordinate. Another important aspect is the very strong correlation between the x - coordinate and the station clock offset which casts some doubt upon the reliability of this component. On the other hand, however, the HartRAO y - coordinate was determined most reliably. The individual results are scattered only in narrow margins and the geometrical configuration is optimal for the y - coordinate determination since correlations with other parameters are minimal. Therefore a shift in the HartRAO y - coordinate has been excluded so far as a possible solution to cure the offset. Further investigations are necessary for a final solution of this problem.

4. CONCLUSION

Although further work is necessary before we can investigate possible short term variations in the daily pole positions, these experiments have proved the potential of a very long north-south baseline for polar motion determinations. Owing to its location the HartRAO - Wettzell baseline is most sensitive to the y-pole-coordinate but the determination of the x-pole-coordinate is also very satisfactory for such a short observing time. Formal errors of ±2 mas for x_p and ±1 mas for y_p, for two hour experiments, as well as a correlation coefficient of only 0.4 between the two components are very encouraging results for further exploitation of this baseline.

5. ACKNOWLEDGEMENTS

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REFERENCE

[1] Herring T.A., Gwinn C.R., Shapiro I.I., Geodesy by Radio Interferometry: Studies of the forced Nutations of the Earth, J. Geophys. Res., 91, No. B5, p. 4745, 1986

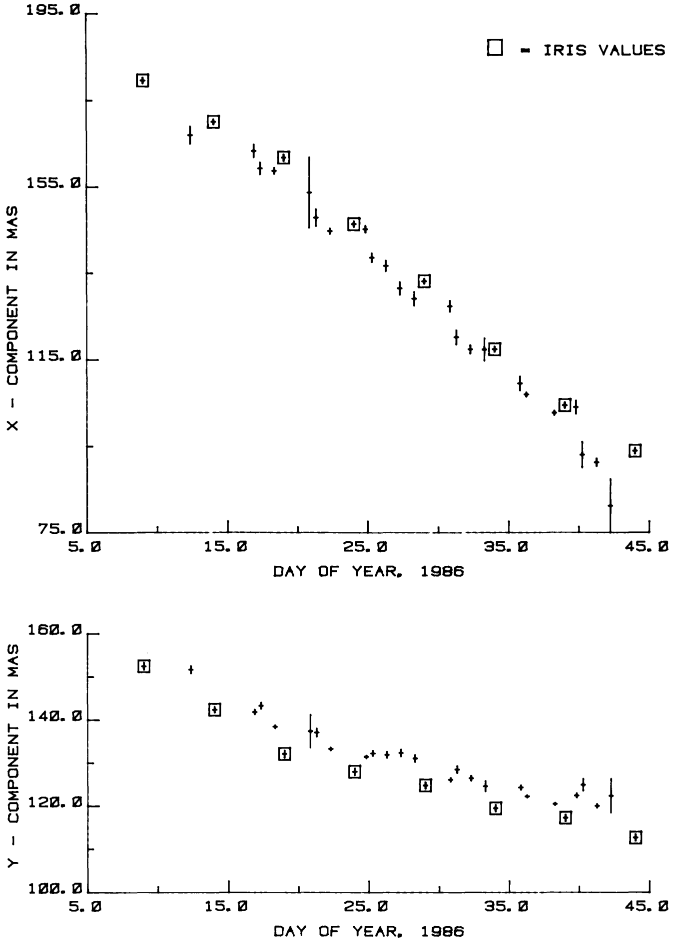

Fig. 1, Pole Positions versus Time.

DISCUSSION

Dickey: You mentioned a lack of sources in the Southern Hemisphere. The DSN has been observing in the Southern Hemisphere for years and has many sources.

Treuhaft: Did you investigate the possibility of troposphere mis-modelling as a contributor to your bias problem?

Reply by Nothnagel: Yes. There was not a large effect due to changing troposphere models.

Reply by Schuh: Observations were taken only above 20° elevations.

Carter: It is hoped that the experiment can be repeated once per year until Hartebeesthoek has its own Mark III terminal.