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RDV77 VLBA Hardware/Software Correlator Comparisons

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Abstract

Results of a hardware vs. software correlation of the RDV77 session are presented. Group delays are found to agree (WRMS differences) at an average level of 4.2 psec and with a noise floor of ~2.5 psec. These RDV77 comparisons agree well with several previous correlator comparison studies.

1. Correlation at the VLBA

The VLBA hardware correlator has now been replaced with the VLBA-DiFX [1] software correlator. This is the VLBA's implementation of the Distributed F/X (DiFX) software correlator, written by Adam Deller [2] and first used at Swinburne University in Australia. The GSFC VLBI group agreed to do a hardware/software (HW/SW) correlator comparison using RDV77 to help validate the software correlator's implementation for geodetic and astrometric sessions. This paper presents results of that comparison.

The RDV77 session ran on October 7-8, 2009. It used the ten VLBA[1] antennas plus the Mark IV antennas at Hobart, Kokee, Ny-Ålesund, Tsukuba, and Wettzell. It was correlated on both the VLBA hardware correlator and the new VLBA-DiFX software correlator in Socorro in November 2009. RDV77 also used 2-bit sampling for the first time in an RDV.

2. Differences Between the Two Correlations

There were some minor differences between the two correlations, which could add noise to the comparisons. Different site and source á prioris were used; therefore the correlator models differed. This should not matter though, since we are comparing total observables. Also, the integration times were slightly different, 4.00 seconds for the SW correlator and 4.063232 seconds for the HW correlator, so scan start and stop times, and scan durations will differ. The HW correlator takes longer to sync up and will correlate all data on disk, so the user must flag off-source times. The SW correlator correlates only when the antennas are on-source.

3. The Two Geodetic Solutions

Both versions were processed using AIPS in a similar manner to obtain the group delay and rate observables. Measured phase cal offsets were applied at the VLBA sites. Manual phase offsets were determined using the same scans in the two versions and applied at all sites. Flagging times

[1]The VLBA is a facility of the National Radio Astronomy Observatory (NRAO) which is operated by Associated Universities Inc., under cooperative agreement with the National Science Foundation.

(when the antennas were off-source) were applied to both sets. The data was fringed in AIPS and the resultant observations were given identical time tags in the two versions.

The two versions were analyzed using Calc/Solve. Below are the solution statistics. There were 22,044 scheduled observations. Problems at Tsukuba (five hours lost due to a typhoon) and MK-VLBA (four hours lost due to an azimuth ACU failure) are the main reasons for the lower total number of observations. The SW version has fewer total observations, but it uses ~1500 more observations in the Solve solution.

	HW	SW
Number total observations:	21595	20938
Number usable observations:	18127	19386
Number used observations:	17019	18541
Number obs. not used:	4576	2397
Solve fit (psec):	32.55	33.93

4. Group Delay and Rate Comparisons

Group delays were differenced for each baseline, then a weighted average value was subtracted out, and a weighted RMS was then computed. Observation pairs were excluded if one or both were not used in the solutions. Also excluded were pairs in which one SNR was much smaller than the other (discussed later). Plotted in Figures 1 and 2 are the WRMS total delay differences versus baseline length for the X-band and the S-band data. A similar plot is shown for the X-band delay rates (Figure 3).

Group delays show a clear baseline length dependence. X-band WRMS differences vary from a minimum of ~2.5 psec (~0.75 mm) for the KP-VLBA/OV-VLBA baseline, up to ~32 psec for Hobart/Ny-Ålesund. The overall WRMS delay difference for all good matches in 104 baselines is 4.22 psec at X-band. The plots are coded by the type of baseline. VLBA/VLBA baselines show the smallest WRMS differences due to their generally higher SNRs and lower formal errors.

In Figure 4 are plotted X-band group delay signal-to-noise ratios (SNRs) versus group delay differences for individual observations. These show, as expected, a clear dependence on SNRs. Delay differences quickly drop to minimal values as the SNR increases.

5. SNR Comparisons

Some large outliers were found in the delay comparisons. These were found to be mostly due to pairs in which one of the SNRs (and fringe coherence coefficients) was considerably smaller than the other, but the integration times were approximately the same. Most of these are cases where the HW version SNR is much less than the SW version. This indicates some problem in the processing, possibly in the setting of flagging times, which is critical for the HW version but not the SW version. The normal database editing eliminated most of these points from the HW version Solve solution, which essentially explains the difference in the number of observations used in the two solutions.

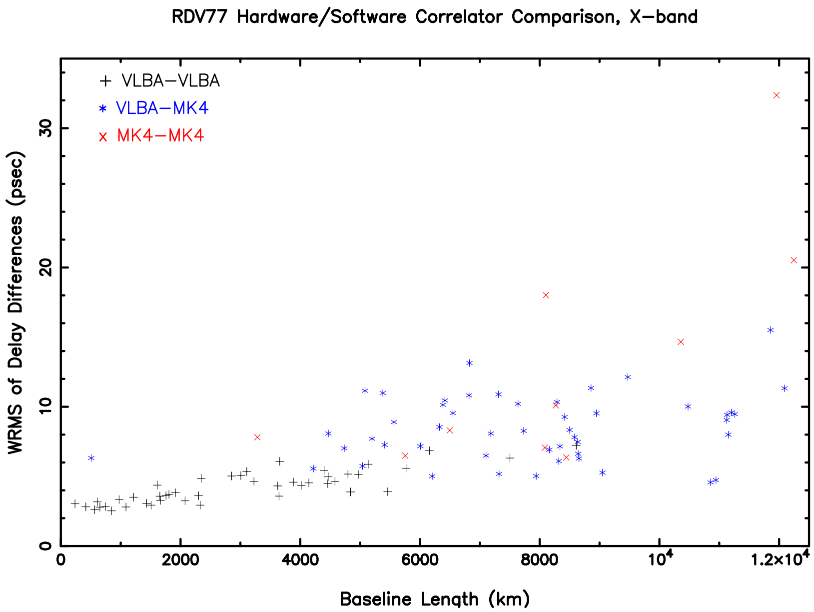

Figure 1. X-band WRMS group delay differences vs. baseline length.

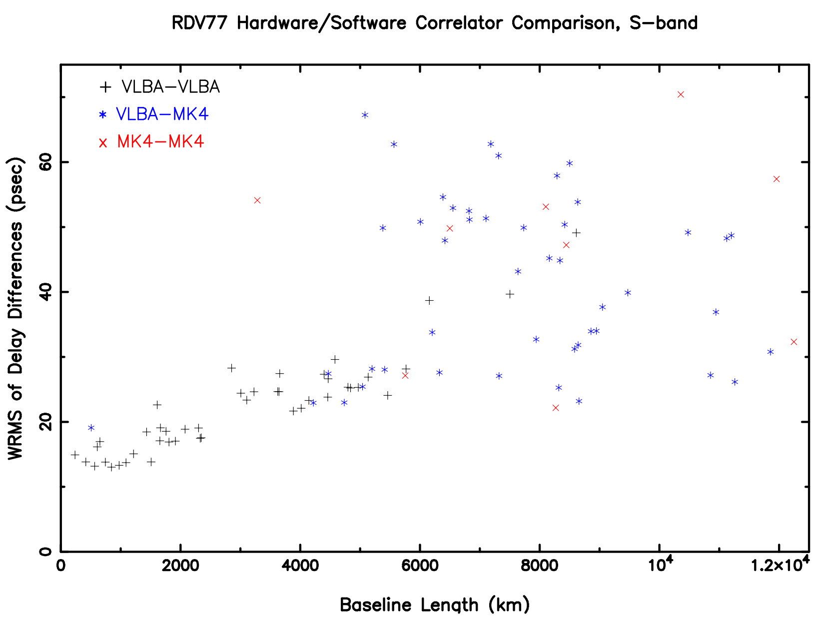

Figure 2. S-band WRMS group delay differences vs. baseline length.

6. Comparison to Earlier Correlator Comparisons

A few earlier geodetic/astrometric correlator comparisons have been made. Nothnagel et al. [3] compared Mark III vs. Mark IV and repeated Mark IV vs. Mark IV correlations. Gordon [4] and Petrov et al. [5] compared 8 stations of RDV22 correlated at the VLBA and on the Mark IV correlator at Haystack Observatory. The editing criteria for these other comparisons differed,

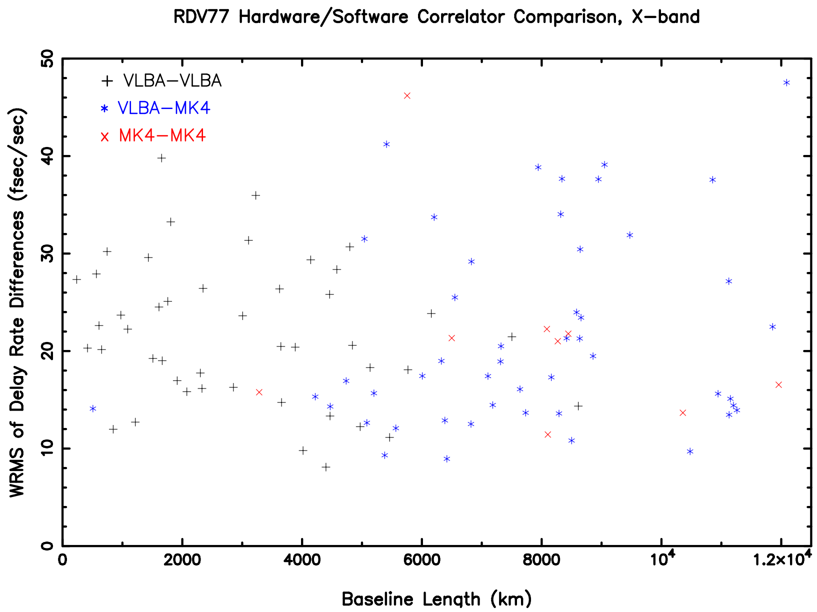

Figure 3. X-band WRMS delay rate differences vs. baseline length.

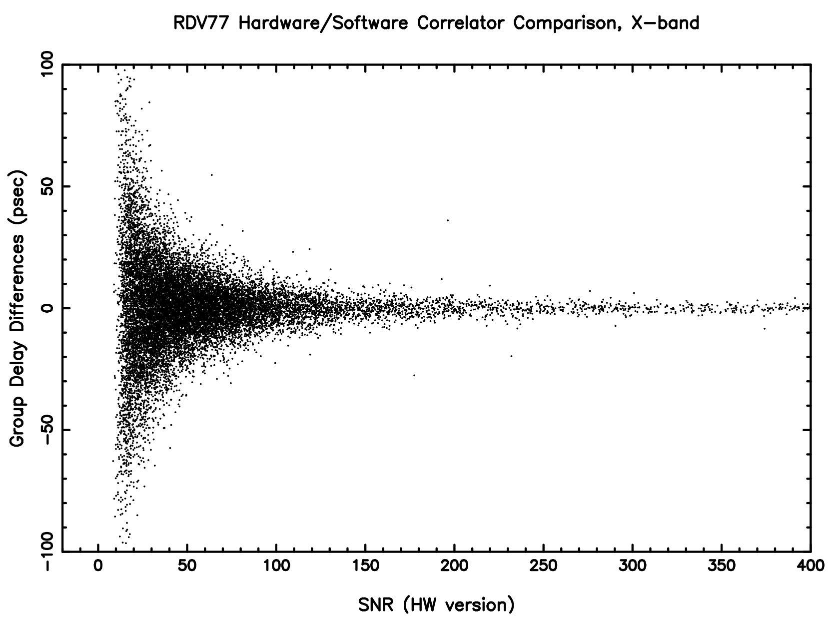

Figure 4. Distribution of individual group delay differences vs. SNRs.

but all are in general agreement. In Figure 5 are plotted the WRMS group delay differences from those other studies along with the results of this study for X-band.

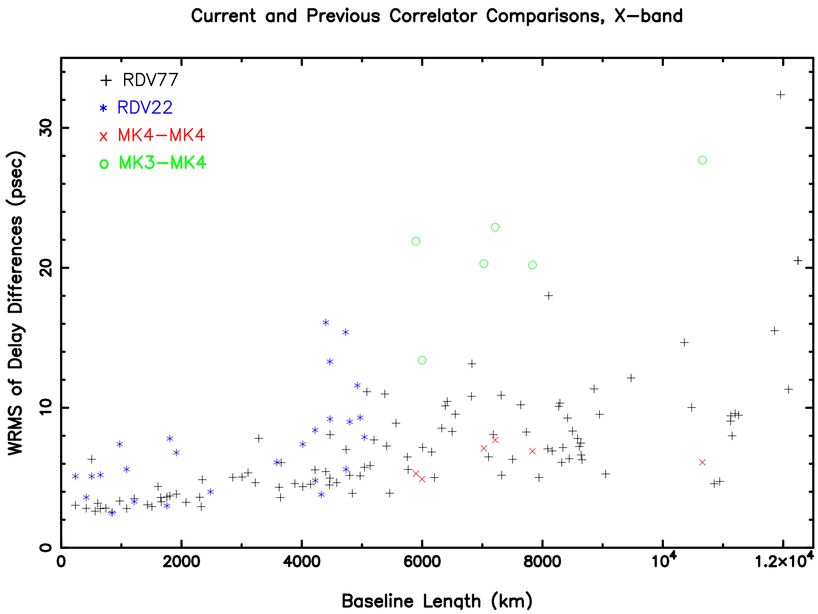

Figure 5. Group delay WRMS differences from this comparison and from earlier correlator comparison studies.

7. Conclusions

Weighted RMS delay differences per baseline at X band show a noise floor of ~2.5 psec, or ~0.75 mm of light travel time, and an average value of ~4.2 psec (~1.25 mm) over all baselines. The comparisons shown here compare very well to previous correlator comparisons. With its greater data yield, we believe this indicates that the new VLBA software correlator performs at least as well as the older hardware correlator. This gives us confidence that the switchover to the software correlator will have no adverse effect on future RDV or other VLBA astrometry/geodesy sessions.

References

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[2] Deller, A.T., S.J. Tingay, M. Bailes, and C. West, DiFX: A software correlator for very long baseline interferometry using multi-processor computing environments, PASP, **119**, 318, 2007.

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