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Limitations to Dual Frequency Ionosphere Corrections for Frequency Switched K-Q-Band Observations with the VLBA

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Abstract

A series of VLBA experiments were carried out at K and Q bands for astrometry and imaging within the KQ VLBI Survey Collaboration. The paired K and Q observations of each source are separated by approximately 3 minutes of time. We investigate the delay effect of the ionosphere between K and Q bands involving the interscan separation. This differential delay effect is intermixed with the differential fluctuation effect of the troposphere.

1. Dual-Band Ionospheric Delay Reduction

In dual-band VLBI observations the delay effect of the ionosphere is greatly reduced by forming the ionospheric-delay free combination of the dual delay observables:

$$\tau = a\tau_1 + b\tau_2. \tag{1}$$

The two coefficients

$$a = \nu_1^2/(\nu_1^2 - \nu_2^2), \tag{2}$$
$$b = \nu_2^2/(\nu_2^2 - \nu_1^2) \tag{3}$$

sum to 1, therefore the nondispersive component of the delay remains unaltered. Of course, this treatment assumes that the two observations made at two frequencies are simultaneous. At the Very Long Baseline Array (VLBA), currently only S- and X-band observations can be simultaneously performed. The measurements described in this report (e.g. [1]), involve K (24 Ghz) and Q (43 GHz) band frequencies, therefore a frequency switching is performed in the middle of each source observation. Therefore, we must include appropriate corrections to Eq. 1, which are

$$\tau \rightarrow \tau - b\Delta M - b\Delta K/\nu_2^2, \tag{4}$$

where $\Delta M = M_2 - M_1$ is the nonionospheric model-contribution difference, and ΔK is inospheric-content coefficient difference corresponding to the relation $\tau_{ion} = K/\nu^2$. The differential quantities ΔM and ΔK are not measured; they must be estimated. While we do not a have a solid estimate, S-X band VLBI studies indicate that the average K-band ionospheric delay effect at the VLBA is perhaps 25 ps. The delay effect is distributed among the post-fit observables and residuals. The question is whether such a magnitude of delay effect is reducible by dual-band observations.

2. Tropospheric Fluctuation

The temporal separation between the K- and Q-band observations is nearly 200 seconds. Besides the columnar ionospheric content change between these observations the tropospheric delay also changes. The quasi-static part of this effect can be nearly eliminated by estimating the zenith tropospheric delay. However, the fluctuation effect remains undetermined.

We may estimate the change in average tropospheric fluctuation delay during the scan separation period from the mean tropospheric delay rate. The delay rate is dominated by the water vapor fluctuation [2]. It is found that in the VLBA K-Q experiments the root-mean-square (rms) of the tropospheric delay-rate is 0.08 ps/s. Therefore, a rough estimate of the fluctuation change over 200 s is $0.08 \times 200 = 16$ ps. This value is not an insignificant part of the ionospheric delay to be calibrated. However, as shown in the next section, the system noise is the dominant factor which makes it impossible to perform ionospheric calibration.

3. Results and Conclusion

We have evaluated the distribution of the rms system noise, as calculated by the fringe fitting; the results are displayed in Figures 1 and 2. The distribution is normalized to its theoretical form that should be a χ distribution if the underlying random noise is Gaussian. Note that the ratio of the rms noise at Q- and K-band is about 2. Beside the large rms value, the Q-band distribution also exhibits a non-Gaussian tail.

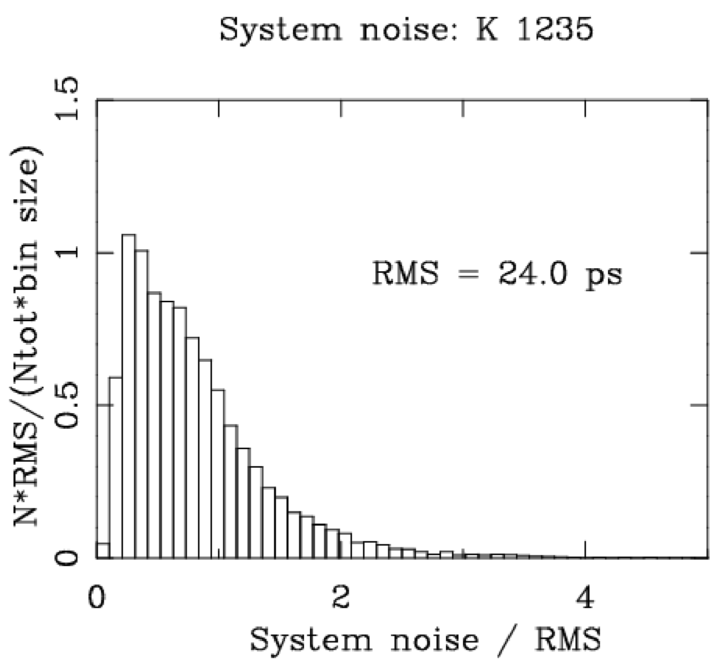

Figure 1. Normalized K-band noise distribution.

The distribution of post-fit residuals of observation, Figs. 3 and 4, exhibit a similar trend. These distribution are also normalized. The K-band residual distribution has a small non-Gaussian component, while the calibrated residual distribution deviates substantially from a Gaussian dis-

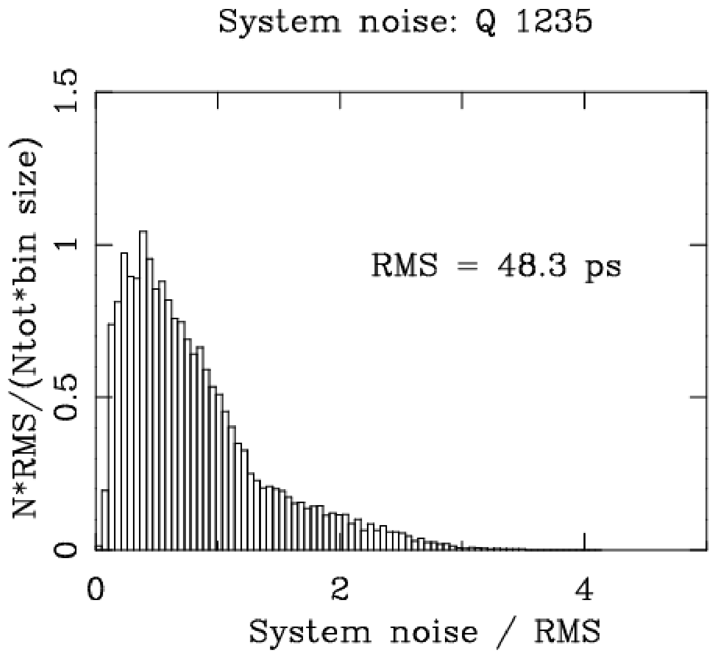

Figure 2. Normalized Q-band noise distribution.

tribution. The calibrated residual distribution is essentially dominated by the Q-band residual distribution with an rms of ≈ 45 ps. The non-Gaussian phenomenon is still under investigation. What is certain is that the rms value of Q-band noise and the corresponding post-fit residuals inhibit estimation of the ionospheric delay not only for switched, but for simultaneous K- and Q-band observation as well. Simultaneous X-K band observations may be a possibility for K-band ionospheric calibration. A 24-h (S/X)-K-(S/X) triple-scan observation sequence was carried out to investigate the ionospheric calibration effect.

4. Acknowledgments

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References

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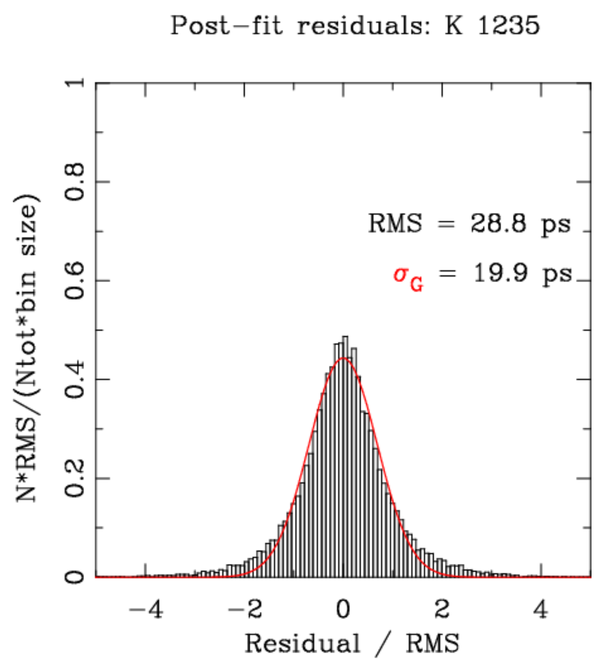

Figure 3. K-band residual distribution, normalized.

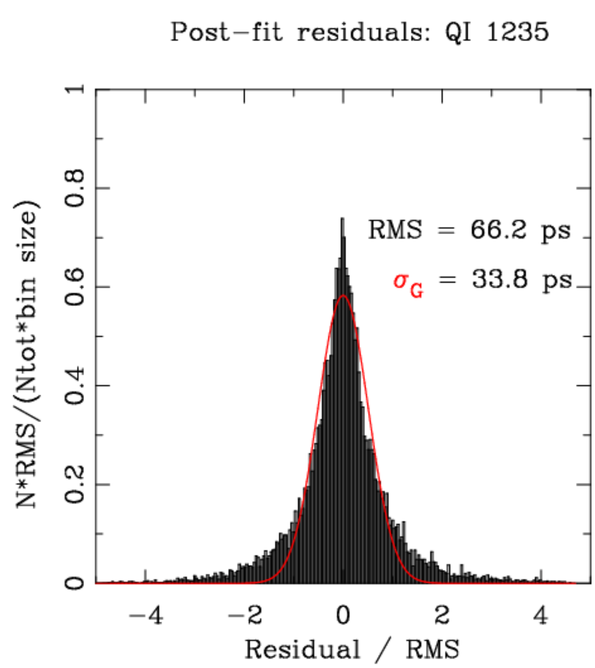

Figure 4. Calibrated residual distribution, normalized.