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On the determination of a Kalman filter celestial reference frame and its application in VLBI analysis

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Kalman filtering has become an established technique for the determination of terrestrial reference frames, as demonstrated for example by the JTRF2014, the International Terrestrial Reference System realization by JPL. The inherent time series representation of the frame is able to take into account irregular effects in the station coordinates, such as unmodeled geophysical loading displacements.

In this study, we use Kalman filtering for the creation of a celestial reference frame (CRF). Having time series of radio source coordinates instead of temporally constant coordinates is beneficial for radio sources that exhibit temporal variations, for example, caused by source structure effects. However, the vast majority of radio sources has been observed on only very few occasions. For these sources, the constant coordinate model is sufficient and considerably more efficient to compute. Therefore, we compute our CRF in two steps; First, constant coordinates of more than 4097 radio sources are estimated in a least-squares adjustment based on normal equations from 5446 VLBI sessions between 1980 and 2016. In a second step, we feed the residual coordinates of 822 radio sources with respect to the constant frame into a Kalman filter and smoother to compute coordinate time series assuming a random walk process. The orientation of the Kalman filter CRF is kept identical to the constant frame from the first step by aligning both to ICRF2 using the 295 ICRF2 defining sources.

Applying the Kalman filter CRF in VLBI analysis, we find differences of up to 30 μas in the WRMS of estimated Earth orientation parameters compared to when using the constant CRF. Concerning the radio source coordinates estimated in the analysis, the WRMS averaged over all radio sources differs by about 15 μas. The estimated coordinate offsets with respect to the a priori CRFs are about 20% smaller for the Kalman filter CRF vs. the constant CRF. Finally, we compare Kalman filter radio source coordinate time series to radio source images depicting the sources' structure. Similarities are found in terms of the expected magnitude of the temporal coordinate variations.