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Detection of Short Period Ionosphere Variations from VLBI Fringe Phases

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Abstract

The usage of fringe phase information from VLBI measurements is a new and challenging field of research, which can be utilized for the detection of short period variations (scintillations) of the ionosphere. A method for the extraction of such disturbances has been developed and it is discussed how dispersive influences can be separated from intra-scan delay variations. It is shown that a short period variation can be detected very precisely, if the SNR is high enough. Physical origins of such disturbances are discussed and fields of application will be mentioned. This paper is an extended abstract of the paper Hobiger et al. (2006, [1]).

1. Introduction

The correlator integrates the observation data, utilizing a-priori values of delay and delay rate, and splits the data into time blocks of a few seconds duration. Usually, post-correlation analyses corrects discrepancies between a-priori values and actual delay and delay rate. But the correlator output (i.e. fringe phase and correlation amplitude for each accumulation period) can be taken directly for studies of delay changes if phases can be connected within each channel. Thus, dispersive delay effects (assigned to ionosphere variations) can be separated from delay changes, when fringe phase information from several channels is used.

2. Functional and Stochastic Model

The fringe phase $\phi_i(t)$ of channel i can be split up into

- a residual delay $\Delta\tau(t)$, i.e. the difference between the theoretical delay, computed from a polynomial of higher order, and the measured delay from single-band delay search,
- an ionospheric contribution, proportional to the difference of the ionosphere conditions between both stations, expressed by $\Delta STEC(t)$,
- a phase offset $\hat{\phi}_i$, which is aligned within bandwidth synthesis by applying the phase-cal signals,
- a random error ϵ caused by the electronics of the receiving system.

Therefore,

$$\phi_i(t) = 2\pi f_i \Delta\tau(t) - 2\pi \frac{40.28}{f_i} \Delta STEC(t) + \hat{\phi}_i + \epsilon \tag{1}$$

where f_i is the RF frequency of channel i. When only using single channel data it is impossible to separate ionosphere contributions from delay changes. But, if fringe phases can be computed for individual channels, it will become possible to distinguish the effects as they are scaled by the corresponding channel frequency. The phase offset $\hat{\phi}_i$ can be determined together with the other unknowns (i.e. parameters describing $\Delta\tau(t)$ and $\Delta STEC(t)$) in the adjustment process. The standard deviation of phase measurements is inversely proportional to their signal to noise ratio (SNR). Therefore the weight matrix used within the adjustment process is given by

$$P_{nm} = \begin{cases} SNR_{nm}^2 & (n = m) \\ 0 & (n \neq n) \end{cases} . \tag{2}$$

3. Possible Fields of Application and Requisites

VLBI is able to detect even smallest variations of the ionosphere with a high time resolution as the sampling rate of fringe phases is equal to the parameter period length (here two seconds). Strong radio sources are necessary to ensure high signal to noise ratio in order to enable phase connection and/or phase unwrapping. If this is guaranteed and if the scan is long enough it should be principally possible to detect all TEC variations of the ionosphere. Therefore one can think of the following application fields:

- Detection of traveling ionospheric disturbances (TIDs).
- Detection of plasma bubbles.
- Monitoring diurnal TEC variations with high precision by special experiments.
- Detection of ionospheric disturbances caused by earthquakes, tsunamis or rocket launches.
- Demonstrating the different reactions of the ionosphere to solar excitations and geomagnetic disturbances.

Besides ionospheric tasks the proposed method gives also a basis for handling intra-scan delay variations and providing phase delay information for geodetic/astrometric purposes or for navigation of spacecrafts.

References

[1] Hobiger, T., T. Kondo, K. Takashima, H. Schuh (2006), Utilizing VLBI fringe phase information for ionospheric studies, submitted to Journal of Geodesy, 2006