

Method of Differential Fringe Phase Tracking

Nobuyuki KAWANO¹, Tetsuo SASAO¹, Tadayoshi HARA¹, Seisuke KUJI¹,
Osamu KAMEYA¹, Katsuhisa SATO¹, Kenzaburo IWADATE¹ and Yoshiharu ASAKI²

¹*Mizusawa Astrogeodynamics Observatory/NAO, Mizusawa, Iwate 023, Japan*

²*University of Electro-communications, Chofu, Tokyo 113, Japan*

Abstract. A new VLBI method called “differential fringe phase tracking” to detect short term variations of a baseline is proposed. Each station has four antennas and they form four VLBI pairs. Two of the four VLBI pairs observe different radio sources and track fringe phases of the sources. The difference between the two fringe phases can be obtained from these observations. The other two VLBI pairs also observe another radio source pair. Since the angular separation between the two radio sources is about 10 deg. tropospheric phase fluctuations are well reduced from the phase differences. The change of a baseline can be detected from these fringe phase differences with an accuracy of a few mm.

1. Introduction

VLBI technique has been used for a few decades in the geodesy and astrometry for obtaining very high angular resolution and very high precision of determining a baseline vector. In the most VLBI observations group delays have been measured. Since the group delay is a derivative of fringe phase with respect to frequency, a wide band receiver is desired to achieve accurate delay determination.

On the other hand, a phase delay observation can give more accurate delay estimate than the group delay observations (see, for example, THOMPSON *et al.*, 1986). For example, if the phase error of a system is 8 degrees at 8 GHz, the delay time can be obtained with the error of 3 ps, which corresponds to 0.8 mm in length. However, in the case of group delay observations, the error would be a few tens ps when the receiving bandwidth is 500 MHz. For this reason we attempt to apply the differential phase delay observation to geodesy and astrometry.

2. Differential Fringe Phase Tracking

Figure 1 shows the outline of the method of differential fringe phase tracking. Each station has four antennas and they form four VLBI pairs. A hydrogen maser is commonly used as a frequency standard at each station. The pairs observe different radio sources, 1, 2, 3, and 4 in the directions of s_1 , s_2 , s_3 , and s_4 respectively. One set of two VLBI pairs observes relatively close radio sources 1 and 2 at the same time. The other one observes close radio sources 3 and 4 which are not necessarily close

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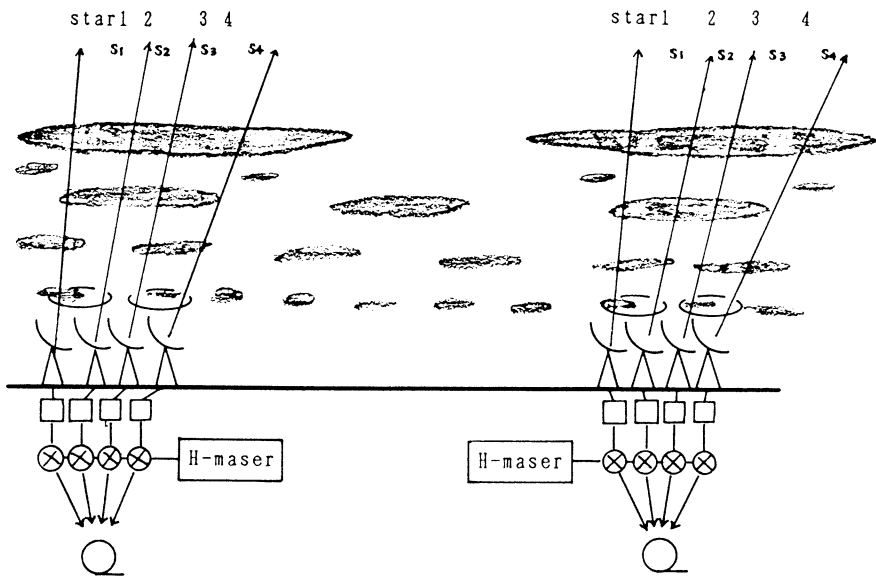


Fig. 1. Outline of differential fringe phase tracking.

to 1 and 2. If these observations are carried out continuously, two series of continuous differential fringe phases are obtained and two dimensional short term variation in the orientation of the baseline vector can be detected.

In order to get the full three dimensional change of the baseline, three series of the differential fringe phases are desired. For this purpose, one can observe two radio sources alternately with one of the VLBI pairs, for example, first radio source 2 and then another source 2'. The set of the two VLBI pairs then yields two series of the differential fringe phases by subtracting the phases of the source 1 from those of 2 or 2'.

3. Tropospheric Effect

The accuracy of the delay measured with the group delay method is limited by atmospheric delay variations, especially tropospheric ones. SASAO *et al.* (1993a, b) have shown that the tropospheric delay variation as well as the phase noise due to a frequency standard can be eliminated from differential phase delays with the differential VLBI technique.

Mean error of the difference path length in the differential phase delay due to the tropospheric fluctuation $c \cdot \delta t$ is given by

$$c \cdot \delta t = \sqrt{2} \cdot 1.3 \cdot p / T^{2.3} (\text{cm}). \tag{1}$$

p : angular separation in deg, T : integration time in sec., c : light velocity.
 Assuming the angular separation of 10 degrees and the mean time of 3600 seconds, the mean error results in 0.8 mm.

The mean error in the determination of the baseline component parallel to the difference vector of two sources, δD_{\parallel} is given by

$$\delta D_{\parallel} = 100 / T^{2.3} (\text{cm}). \tag{2}$$

These results suggest that the tropospheric effect in the baseline determination can be reduced down below 5 mm for an hour observation. The error of the baseline determination is not a function of the separation angle as far as the radio sources are observed near zenith.

4. Observations of Differential Fringe Phase

EDWARDS (1990) observed angularly close two radio sources A and B alter-

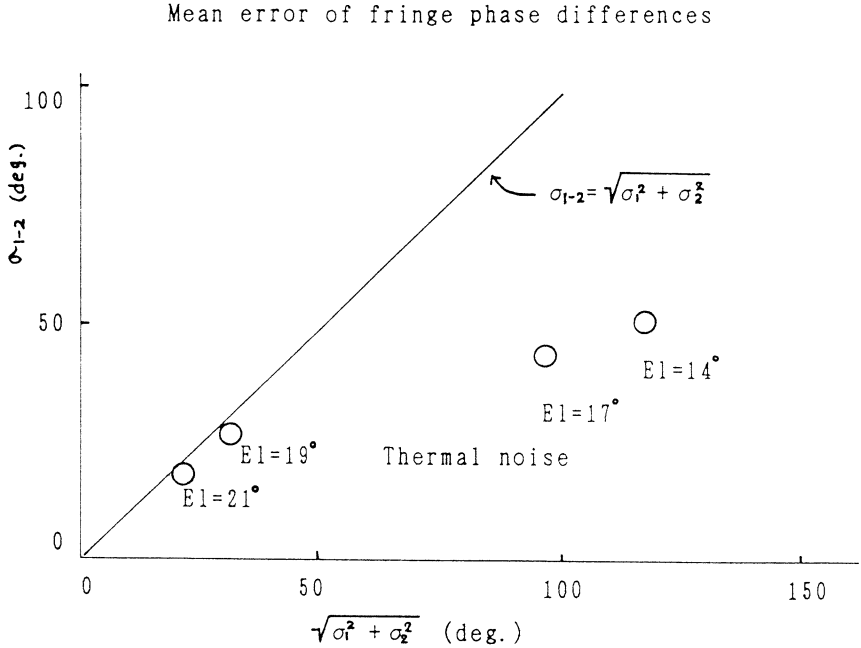


Fig. 2. Mean error of fringe phase differences.

nately. Differential fringe phases were formed from triplets of “A-B-A” observation sequences. The fringe phase of the source A at the time when the source B was observed, was derived through interpolation between two A observations. The standard deviation of differential fringe phases obtained every 8 minutes was 16 ps. This deviation is consistent with the one estimated by Eq. (2).

We demonstrated the capability of differential VLBI using two pairs of VLBI antennas. The method is called “4-element method”. Each station has two antennas and the two VLBI pairs observed close two radio sources simultaneously. The differential fringe phases were obtained continuously. Figure 2 shows the mean error of the differential fringe phases vs. the sum of the mean errors of the two fringe phases during 5 minutes. The mean error of differential fringe phases is considerably less than the sum at low elevations where the atmospheric effect is most significant. This result means that the atmospheric delay fluctuations are well removed.

5. Estimation Error of Baseline Change

If the baseline changes during the period of the differential fringe phase tracking, the difference of the observed fringe phases with two VLBI pairs shifts. The change is detected through the phase shift. We assume that the observation error of the phases is 0.8 mm and the baseline is the one proposed in the VERA project. Hence, the baseline length is 2277 km and its declination is -38 deg. Figure 3 shows the estimation error of the baseline change when two VLBI pairs observe two different radio sources of the declination 0 deg. with the separation angle of 10 deg. along the right ascension. In Fig. 3 the abscissa is hour angle and the ordinate is the estimation error. It is clear that this method can detect a few mm change of the

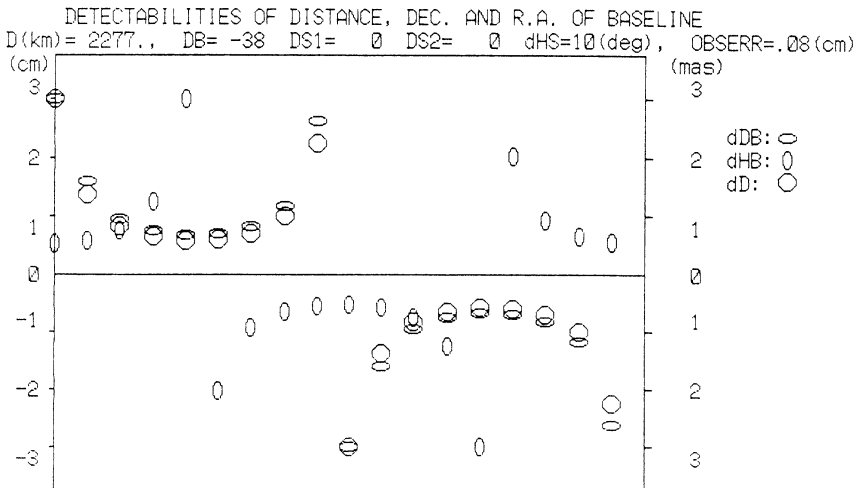


Fig. 3. Detectabilities of distance, declination and right ascension.

baseline. If we extend such observations to an 8000 km baseline, the estimation error in the direction of right ascension and declination can be reduced to 0.1 or 0.2 mas.

6. Conclusion

We proposed a new method of the differential VLBI for geodetic applications. Although the method of differential fringe phase tracking needs a complicated VLBI system such as four antennas, stabilized transmission lines etc. it has the great advantage of detecting a few mm and sub-mas short term (hourly) variations of a baseline.

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