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An Analysis of NTSC's Timekeeping Hydrogen Masers† ⋆

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Abstract In this article, the hydrogen masers in the NTSC (National Time Service Center) timekeeping laboratory are tested. In order to avoid the impact of larger noise of caesium atomic clocks, TA(k) or UTC(k) is not used as reference, instead, the four hydrogen masers are mutually referred and tested. The frequency stability of hydrogen masers is analyzed using the four-cornered hat method, and the Allan standard deviations of each single hydrogen maser in different sample times are estimated. Then, according to the characteristics of hydrogen masers, by removing the trend term, excluding outliers, and smoothing the data with a mathematical method to separate the Gaussian noises of hydrogen masers, and finally by through the Kolmogorov-Smirnov test, the Gaussian noise of each hydrogen maser is estimated.

Key words astrometry—time—methods: statistical

1. INTRODUCTION

A timekeeping laboratory takes the responsibility of generating the primary standard of a state or a region[1], and the quality or the precision of timekeeping depends to a great degree on the composition of the timekeeping system: (1) atomic clocks, (2) the system of primary clocks, (3) the algorithm of atomic time, (4) the frequency control algorithm

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of primary clocks, and so on[2]. There exist in each part some noises or errors[3], which affect the quality of signals of frequency standard generated by the timekeeping system. At present, in order to raise the accuracy of timekeeping, the great nations and main developing countries in the world all attach much importance to the researches on the noises and errors of the time, and invest for them.

In pace with the change of the algorithm of atomic time of BIPM (Bureau International des Poids et Mesures) in 2014, the weight of hydrogen maser has been increased by a wide margin, and it demonstrates a more important position. Meanwhile, hydrogen masers have been adopted as the primary clocks in the main time laboratories of the world. As compared with the other time laboratories in the world, in the NTSC timekeeping laboratory the hydrogen masers are less in quantity (2, with the codes H226 and H227), and have worked over 10 years, and the caesium atomic clocks are still used as the primary clocks. Although their timekeeping precision remains to be internationally advanced, the NTSC has newly introduced 2 hydrogen masers (with the codes H296 and H297), so as to follow the tendency of the timekeeping development in the world, and to lay a technical foundation for the calculation of the local atomic time TA(k) and the primary clock control.

The short-term stability of the newly introduced hydrogen masers surpasses that of the caesium atomic clocks, and, probably, that of the two existing hydrogen masers. As there is no reference standard of higher grade, it is difficult to test and to estimate the performance of these two hydrogen masers.

As the core of timekeeping, the atomic clocks generate pulse signals and frequency signals, the traditional method to analyze their frequency stability is to calculate their Allan deviations as their stability indices, namely to analyze mainly the 5 kinds of basic noises of atomic clocks[4]. In this paper, Gaussian noises are dissociated with the Vondrak smooth method and Kolmogorov-Smirnov test, and an estimation of their Allan deviations is given for a more comprehensive knowledge of their performance.

2. ALLAN VARIANCE ESTIMATION

2.1 Definition of Allan Variance[5]

The definition of Allan variance is characterized by the calculation of difference sequence. The sequence after difference operation is stationary, and its variance remains invariant with the sample number. If there is no delay between two successive samples of known value $\bar{y}_k^\tau$, the semi-average of its two variance samples is equal to the Allan variance, hence

$$\sigma_y^2(\tau) = \frac{1}{2}\mathrm{E}\left\{\left(\bar{y}_{k+1}^\tau - \bar{y}_k^\tau\right)^2\right\} , \quad (1)$$

in which $\bar{y}_k^\tau = \frac{1}{\tau}[x_{k+1} - x_k]$, and x_i is the sequence of equations of time, and it is obtained that

$$\sigma_y^2(\tau) = \frac{1}{2\tau^2}\mathrm{E}\left\{[x_{k+2} - 2x_{k+1} - x_k]^2\right\} . \quad (2)$$