# Master Clock for Real Time Realization UTC(SU) Paper Clock

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## INTRODUCTION

Russian national time scale UTC (SU) is a "paper" clock based on ensemble of H-masers and there are no clocks which exactly realize this time scale in the VNIIFTRI Time Standard Division. An as a usual "paper" clock UTC (SU) is produced somewhat delayed.

Along with it there are a few applications which need real time realization of the UTC (SU). First of all these are different broadcasting and time transfer systems, e.g. NTP servers, GPS/GLO common view time transfer. Such applications need, especially last one, more or less accurate (within few ns) and reliable physical 1 ppS signal which realizes the UTC (SU) time scale.

The paper will deliver main requirements, design features of the future MC (SU) and theoretical estimations of the expected performances.

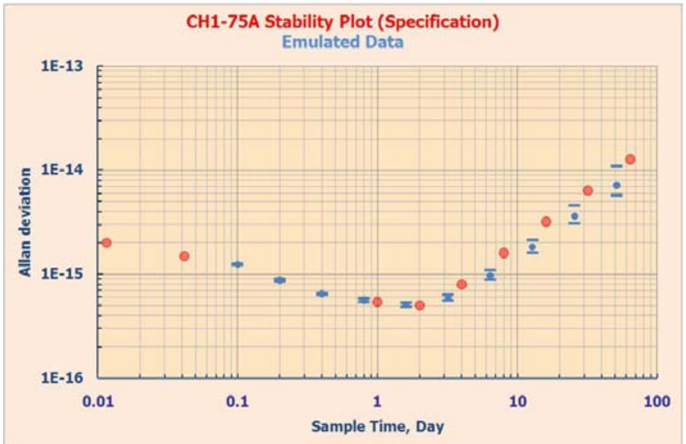
## THE METROLOGICAL REQUIREMENTS FOR MASTER CLOCK

The metrological requirements for Master Clock originate first of all from real time GPS/GLO common view time transfer needs. Because of common view time resolution of modern links based on multichannel receivers is a little bit less than 1 ns for sample time 1 day [1] according to the metrological rules reference signal have contribute at least three times less, so it means somewhat about 0.2 – 0.3 ns. As a rule this value is estimated by Allan Time Variance [2], TVAR. This will be uncertainty type A - $u_A$.

On other hand when one produces synthesized signal, such as 1 pps approximated to the "paper" clock, possible biases, uncertainty type B - $u_B$, may also be limiting factor.

That's why extended uncertainty u equals to square root of quadratic sum of the $u_A$ and $u_B$ will be relevant estimate of total error. In further text we'll deliver uncertainty type A and extended uncertainty for selected algorithms.

## CLOCK MODEL




For data treating within this paper artificial data stream was specially prepared which has similar to typical H-maser statistical and drift properties, Fig.1. Sample time of this data stream was 10 readings within 1 day. Total data volume 400 days.

Fig.1. Frequency stability plot for CH1-75 H-maser according to its specification and corresponding stability dependencies for emulated data

## INVESTIGATED ALGORITMS FOR MASTER CLOCK

To predict time difference and gained time errors between referenced clock and UTC (SU) when controls have been applied a few algorithms were investigated.

First simple linear and square predictions based on different estimation intervals. Estimation intervals varied from 1 day to 10 days. Prediction intervals also varied from 1 to 10 days, Fig.2 and 3. Gained time error at the end

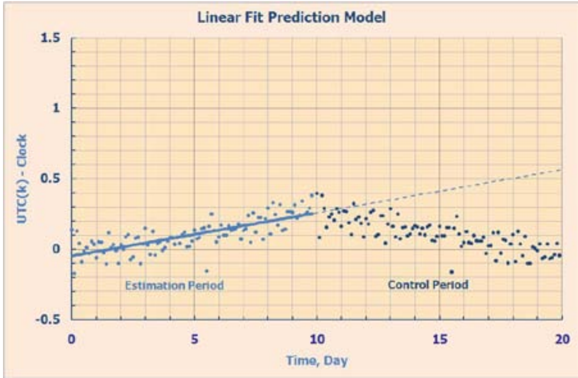



Fig. 2. Linear fit prediction model

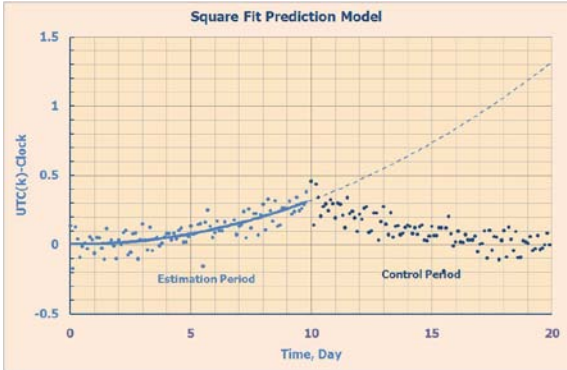



Fig. 3. Square fit prediction model

of estimation interval then evenly removed within control interval. Then estimation interval moved ahead to the end of previous estimation interval.

Strictly speaking the above models is not vital. Because of UTC (SU) "paper" clock is generated in delayed time, on weekdays at least half a day and may be more just after weekend and holidays we consider interesting to investigate metrological properties of so called "Delayed" models. Their principles are demonstrated on Fig.4

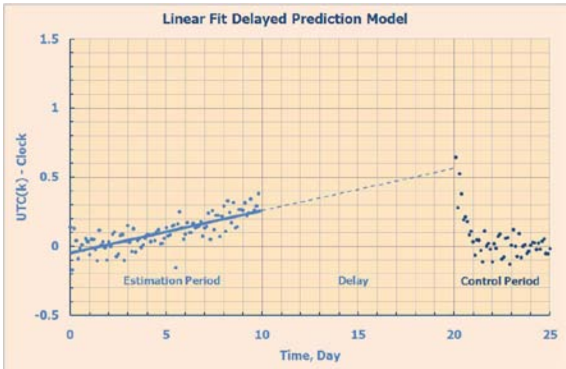



Fig. 4. Linear fit delayed prediction model

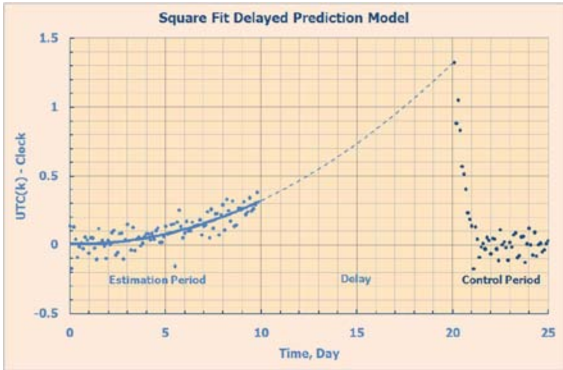



Fig. 5. Square fit delayed prediction model

and 5.

As previously estimation and delay intervals varied from 1 day to 10 days. Gained time error at the end of delay interval removed within 1 day. Such a control is done because the aim of MC is first of all minimize time difference between UTC (k) and MC. Then estimation interval moved ahead to the end of previous estimation interval.

## RESULTS

According to list of investigated models a set of corresponding results are presented below. First we start up with most simple one – linear fitting for different estimation and prediction periods, Fig. 7 and 8. At these and following square fitting figures dashed lines correspond to $u_A$ uncertainty and solid lines to extended one. Numbers m/n means: m – estimation period and n – control period. The grey curve on every following figure demonstrates time error gained by free running reference H-maser with stability performances on Fig.1.

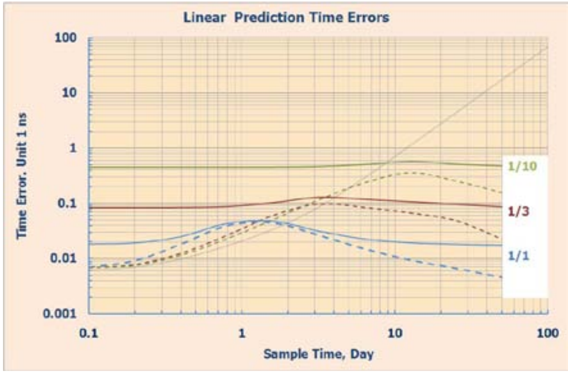



Fig. 6. Linear fit time error for 1 day estimation period

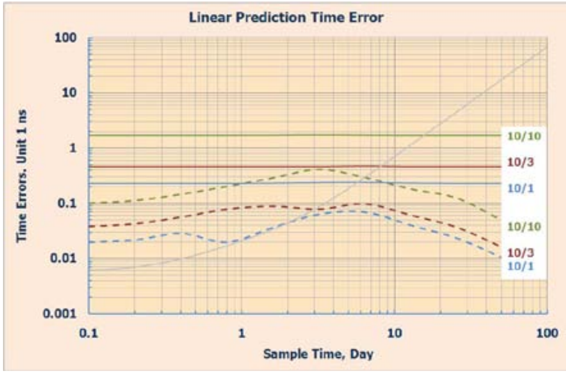



Fig. 7. Linear fit time error for 10 days estimation period

The main difference between these figures is considerably big contribution of systematic for longer estimation period. This means that despite the frequency drift of reference clock is not too much, about $2\times10^{-16}$/day, model feels this source of error.

The next pair of figures, Fig. 8 and 9 presents results of square prediction. These figures confirm to some extend inadequacy of linear fitting, even for short time. On other hand lesser $u_A$ uncertainty and lesser contribution of systematic for 10 days estimation period obviously demonstrate necessity of longer estimation period for adequate square modeling.

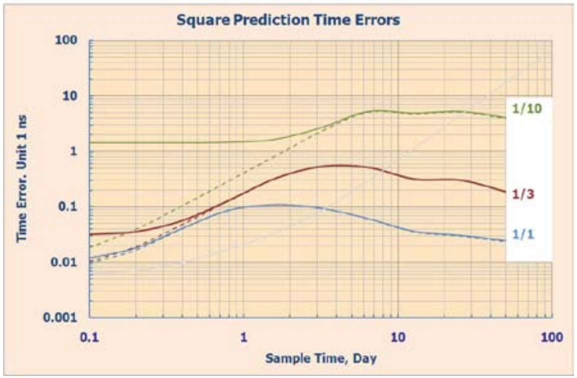



Fig. 8. Square fit time error for 1 day estimation period

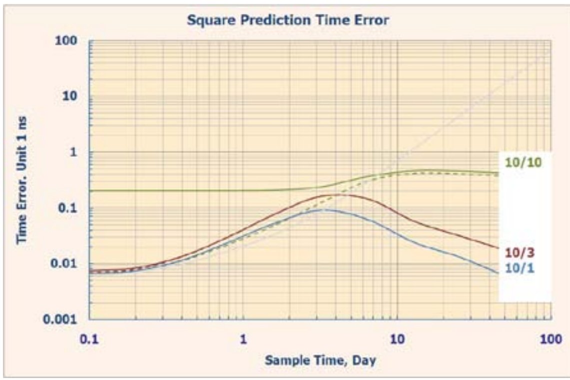
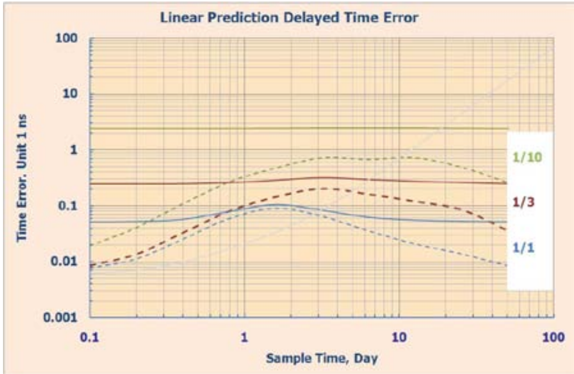



Fig. 9. Square fit time error for 10 days estimation period

As was mentioned earlier UTC (SU) “paper” clock is generated in delayed time. That’s why next portion of figures presents metrological properties of “Delayed” models.

The first pair of figures, Fig. 10 and 11 presents results for linear predictions. Numbers m/n on charts for “Delay” prediction means: m – estimation period and n – delay period. Naturally the $u_A$ uncertainty as well as extended uncertainty is considerably more than similar figures for usual linear predictions. The uncertainty enlargements reaffirms that linear models are not adequate for standards with frequency drift. So one has to conclude that gained time errors of frequency drifting reference standard are strongly dependent on length of linear prediction period and this dependency is mainly due to systematic.



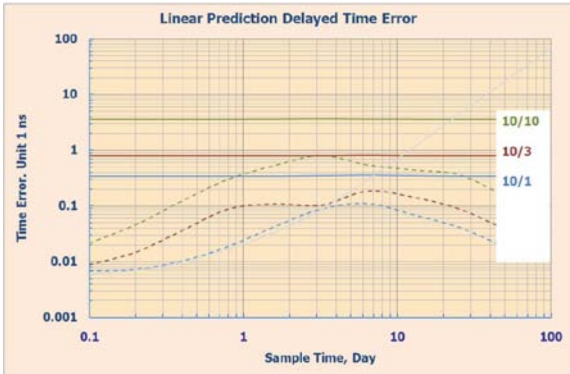
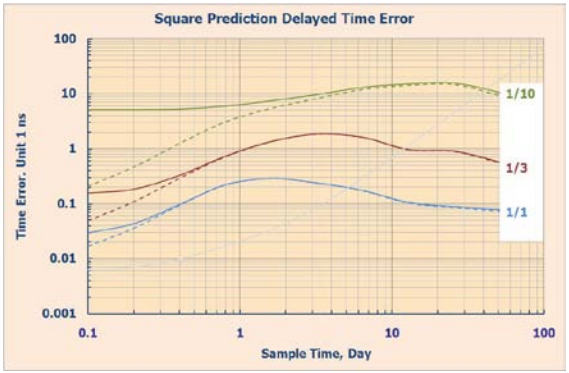




Fig. 10. Linear fit delayed time error
for 1 day estimation period

Fig. 11. Linear fit delayed time error
for 10 days estimation period

The next pair of results demonstrates prediction delayed time errors for square modeling, Fig. 12 and 13.



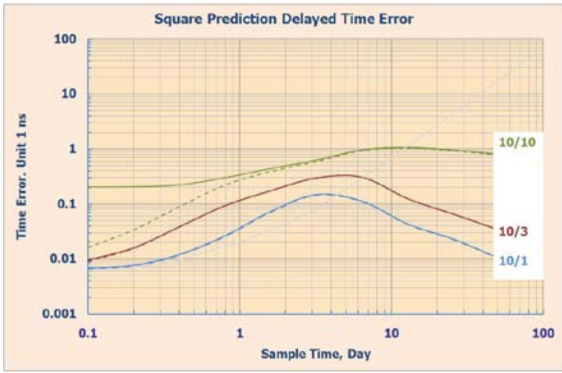




Fig. 12. Square fit delayed time error
for 1 day estimation period

Fig. 13. Square fit delayed time error
for 10 days estimation period

Ones more Fig.12, analogous to Fig.8, confirms that to get accurate square model for clock prediction one has apply considerably longer estimation period for adequate square modeling. On other hand Fig. 9 and Fig.13 comparison shows that adequate model with accurately defined coefficient works quite good, at least in case when estimation period is considerably bigger than delay. More over in both cases, square prediction and square delayed prediction for 10 days estimation period, contribution of systematic is quite negligible.

**CONCLUSION**

This simple data treatment shows that basing on high quality CH1-75 H-maser signal seems quite feasible to create real time 1 ppS - Master Clock - with time difference relative to “paper” clock UTC (SU) less than few tenth ns for sample time from 1 day.

The other conclusion is that clock model has to be essentially square and more over time period for estimation model coefficients has to be adequate to random frequency noises and frequency drift.

**REFERENCES**

[1] Y. Domnin, N. Koshelyaevsky, V. Kostromin, P. Krasovsky and V.Palchikov, “The State Time and Frequency Standard of Russia”, *Proceedings of the 41th Annual Precise Time and Time Interval (PTTI)*

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[2] D. W. Allan, “Time and frequency (time domain) characterization, estimation and prediction of precision clocks and oscillators”, *IEEE trans. UFFC, vol UFFC - 34, n° 6, Nov. 1987.*