PRELIMINARY RESULTS OF THE TTS4 TIME TRANSFER RECEIVER INVESTIGATION

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Abstract

Three new TTS4 GPS/GLONASS/GALILEO time transfer receivers (#119, #121 and #122) have been installed in VNIIFTRI facility and investigated at a short baseline. These instruments have been compared first with each other and authorized receiver type TTS3 #026, which in-turn have been differentially calibrated relative to the BIPM receiver. Then receiver TTS4 #121 was moved to Khabarovsk and installed in a new secondary time laboratory facility. During these experiments, receiver #122's software was updated from version 2.8 to 2.11.

This paper delivers detailed results, both short baseline and long (more than 6,000 km) baseline.

INTRODUCTION

TTS3 GPS/GLONASS time transfer receivers **[1]** are now well known instruments in many laboratories, first of all in those which deal with GLONASS. There are at least eight such instruments in VNIIFTRI and our secondary laboratories. Keeping in mind the new GNSS GALILEO, the new L5 GPS frequency, and the GLONASS full constellation, VNIIFTRI has bought three new TTS4 GPS/ GLONASS/GALILEO time transfer receivers.

At first all these instruments were installed in a VNIIFTRI facility, Mendeleevo, and were compared at short baseline against each other and the TTS3 time transfer system #026, which plays the role of authorized instrument to link UTC(SU) time scale to the world timing community. TTS3 time transfer system #026 have been at least two times differentially calibrated relative to the BIPM TTS3 transportable time transfer system #012 **[2]** and used as the master instrument for calibration needs.

After successful calibration, TTS4 instrument #121 has been moved to the Khabarovsk secondary time laboratory and tests have been continued in both locations: in Mendeleevo at short baseline and between Mendeleevo and Khabarovsk at a distance of more than 6,000 km.

THE FIRST STAGE EXPERIMENTS

The first stage of investigations continued for about three weeks in June 2011 and was performed on a short baseline at VNIIFTRI.

THE EXPERIMENTAL SETUP OF THE FIRST STAGE EXPERIMENTS

The experimental setup of the first stage experiments consisted of:

- time transfer system TTS3 # 026 with antenna MarAnt+ #2634, software version 1.124;
- time transfer system TTS4 # 119 with antenna Leica AR25 #09330030, software version 2.8;
- time transfer system TTS4 # 121 with antenna Leica AR25 #10210013, software version 2.8;
- time transfer system TTS4 # 122 with antenna Leica AR25 #10210020, software version 2.8.

All antennas have been installed on the concrete base in close vicinity to the laboratory room, Figure 1.

Figure 1. TTS's antenna layout.

The length of antenna cables type FSJ1 from ANDREW outside the laboratory room did not exceed a few meters. Before differential comparisons, coordinates of the all antennas were determined with an uncertainty of about 1 cm.

All receiver units have been located in the thermostabilized laboratory room (Figure 2), which has a temperature stability better than 1 K.

Figure 2. TTS3 #026 and TTS4 #119 and #122 units layout.

In this room all necessary distributing 5 MHz and 1 PPS amplifiers have been located also. All TTS have been fed by 5 MHz and 1 PPS reference signals from the same H-maser. The 1 PPS reference signal feeder delays have been measured with an uncertainty of ≤ 0.5 ns and introduced to the receivers.

THE RESULTS OF THE FIRST STAGE EXPERIMENTS

All receivers involved in the experiment produced data files in accordance to cggtts_format_v2.pdf **[3]** which were then processed. Processing consisted of three consecutive steps:

- calculation differences $REFSYS_{receiver\ 1}$ - $REFSYS_{receiver\ 2}$;
- calculation of the mean value of previous differences for all visible GPS or GLONASS satellite within session;
- refining session's mean values from outliers.

The main results of the receiver reading differences and output of the processing for GPS L1C signals during the first stage experiments are depicted in Figures 3-6.

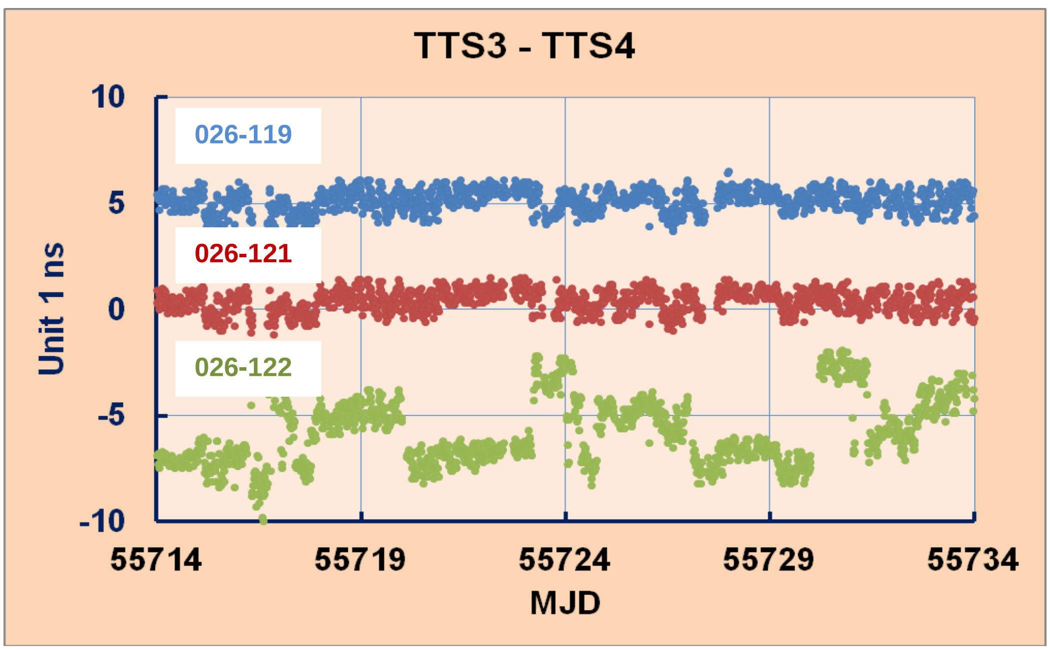

Figure 3. TTS3 #026 and TTS4 #119 and #122 reading differences (receivers #119 and #122 readings are artificially biased).

Somewhat less noisy results are depicted in following Figure 4 relative to TTS4 #119.

The obvious conclusion from comparing Figure 3 and Figure 4– TTS4 receiver # 122 manifests abnormal performance and has to be additionally investigated.

We do not know the actual reasons for such behavior; nevertheless, it is worthwhile to outline that periodical time steps in TTS4 receiver # 122 exactly correspond to one week, which may be GPS week or solar week when a new data file is opened! Actually these look quite strange, because all TTS4 receivers at our disposal had the same hardware and software versions.

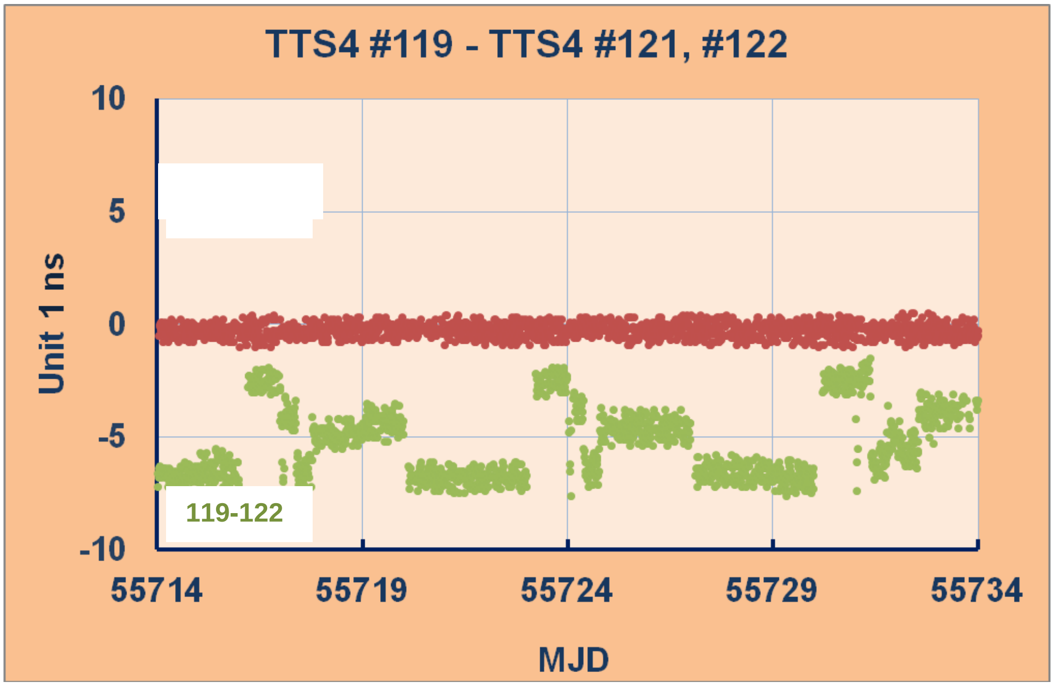

Figure 4. TTS4 #119, TTS4 #121, and #122 reading differences (for receiver # 122 readings are artificially biased).

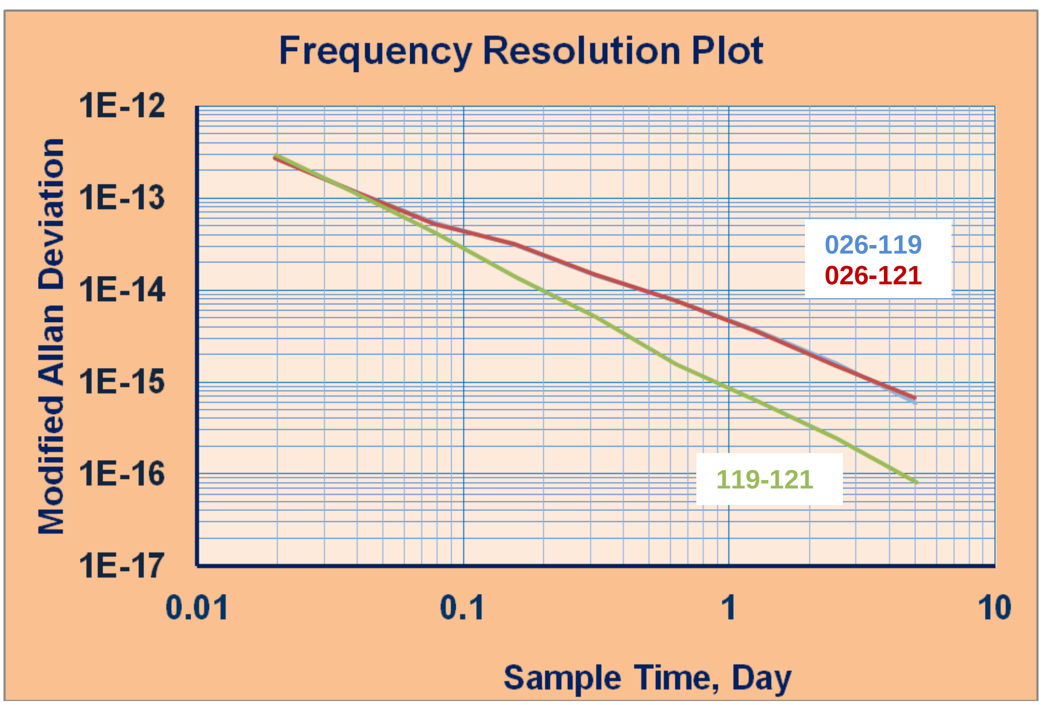

Figure 5. Short Baseline Time Link Frequency Resolution Plot.

Based on the above-mentioned time comparison data for TTS3 #026, TTS4 #119, and #121 receivers, potential time and frequency resolution of corresponding links has been estimated and depicted on Figures 5 and 6. The behavior of TTS4 #122 has to be investigated more deeply.

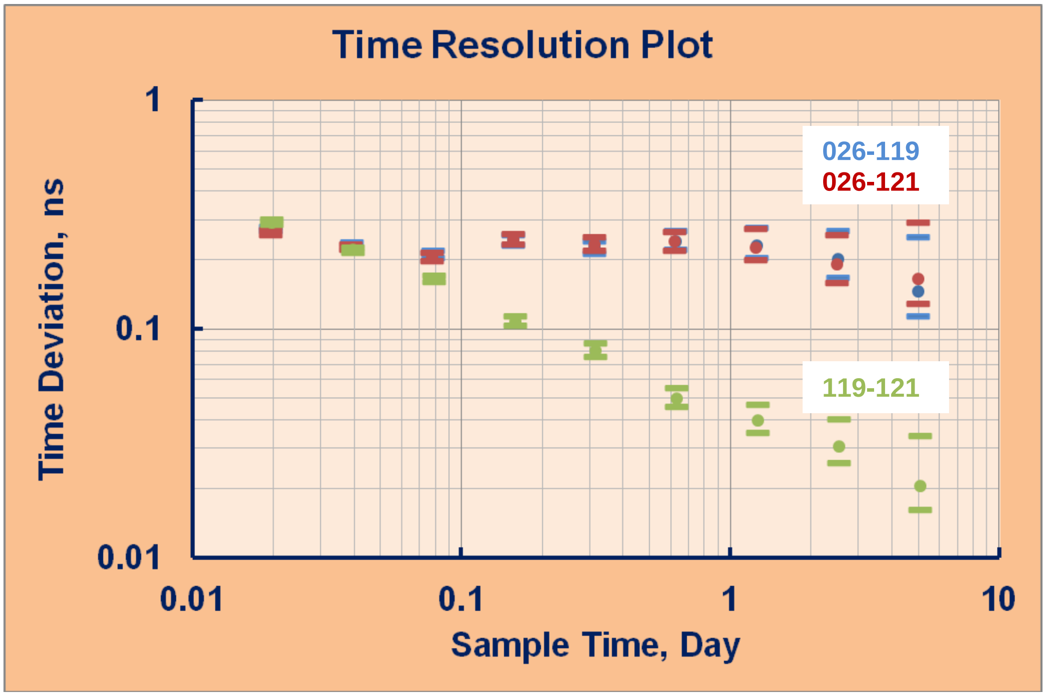

Figure 6. Short Baseline Time Link Time Resolution Plot.

The time link resolution data says us that operable TTS4 receivers have considerably better performances than that of TTS3 – for one day sample time at least five times better!
More over – the nature of noises in TTS4 and TTS3 is quite different. For TTS3 this is flicker PM and white PM for TTS4. Perhaps this is consequence of separate time interval meter in TTS3. In case of TTS4 time interval between external reference and the receiver's internal clock is determined by receiver itself!

THE SECOND STAGE EXPERIMENTS

The second stage of investigations started at the middle of September 2011 and continued up to the end of October.

The experimental setup of the second stage experiments consisted of the same instruments as in stage one. There were only two differences:

- software version of time transfer system TTS4 # 122 in VNIIFTRI has been updated to version 2.11;
- time transfer system TTS4 # 121 with antenna Leica AR25 #10210013, software version 2.8 has been moved to Khabarovsk Secondary Time and Frequency Laboratory, Figure 7.

Figure 7. Time transfer system TTS4 # 121and its antenna. (The column in the middle of metal construction is a heated shaft for antenna feeders.)

THE RESULTS OF THE SECOND STAGE EXPERIMENTS

The results of the second stage experiments consist of two components:

- results on improvement TTS4 # 122 in VNIIFTRI;
- comparative results on the time link between VNIIFTRI, Mendeleevo and Khabarovsk.

In the middle of September, new software v 2.11 was received from Pik Time Systems and TTS4 receiver #122 was updated. Then its short baseline comparison was continued with TTS3 # 026 and TTS4 #119 according to previous methodology and data processing. Consequently, Figures 8-10 display the main improvements.

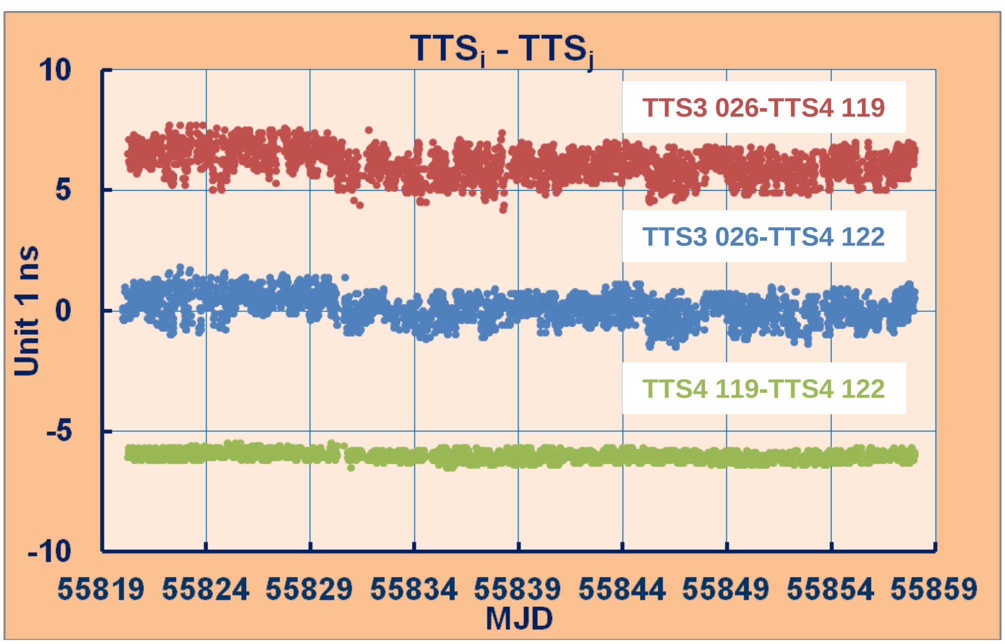

Figure 8. TTS3 #026 and TTS4 #119 and #122 reading differences (for some receivers, readings are artificially biased).

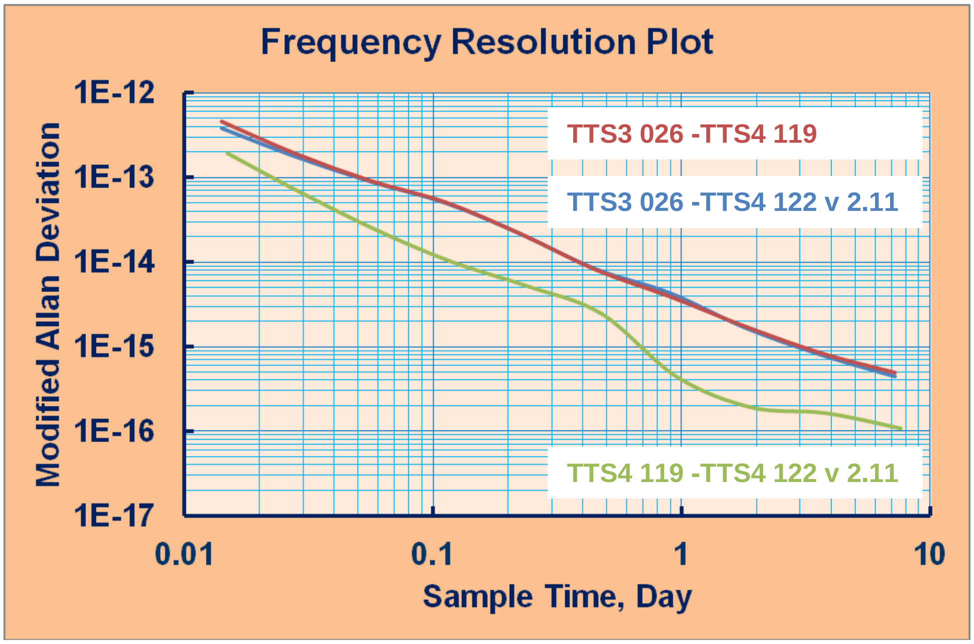

Figure 9. Short Baseline Time Link Frequency Resolution Plot.

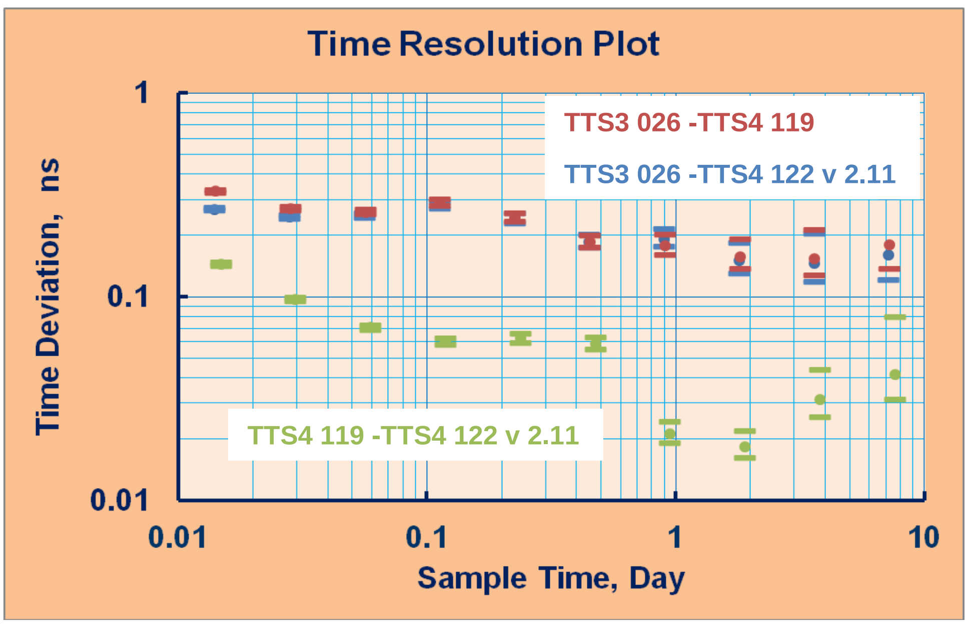

Figure 10. Short Baseline Time Link Time Resolution Plot.

With the updated software, the TTS4 #122 receiver demonstrates performance quite similar to that of TTS4 #119 and #122. On the other hand, it is worthwhile to mention that number of removed outliers in the pair of TTS4-TTS4 receivers is a little bit more than that in the pair of TTS3-TTS4 receivers.

The time scale difference between UTC(SU) in VNIIFTRI, Mendeleevo and UTC(Km), Khabarovsk determined by TTS3 #026 and TTS4 #119, #122 in VNIIFTRI and TTS4 #121 in Khabarovsk, is displayed on Figure 11 based on ionofree combination of the L1P and L2P GPS signals. The TTS4 receivers in VNIIFTRI operate under software version 2.8 for #119 and version 2.11 for # 122, TTS4 receivers in Khabarovsk operate under software version 2.8.

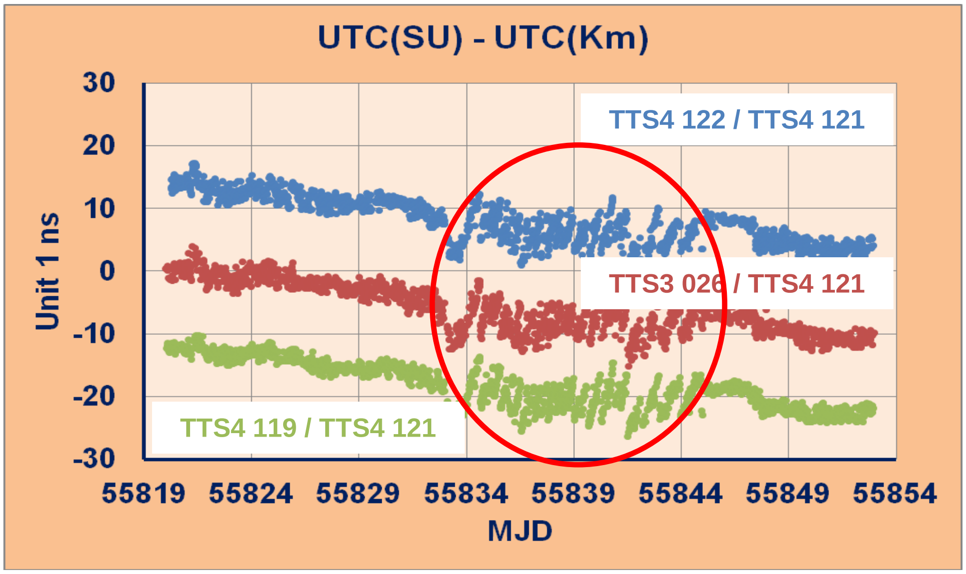

Figure 11. UTC(SU) – UTC(Km) as measured by different receivers (readings are artificially biased).

Depicted in Figure 11, time scale differences UTC(SU) – UTC(Km) measured by different TTS3 and TTS4 demonstrate very good coincidence which reflects correct operation of the old TTS3 #026 receiver and the new ones, TTS4 #119 and #122. On the other hand, the data portion within the oval demonstrates abnormal operation. This happened in TTS4 receiver #121 installed in Khabarovk, perhaps because this receiver operates under software version 2.8.

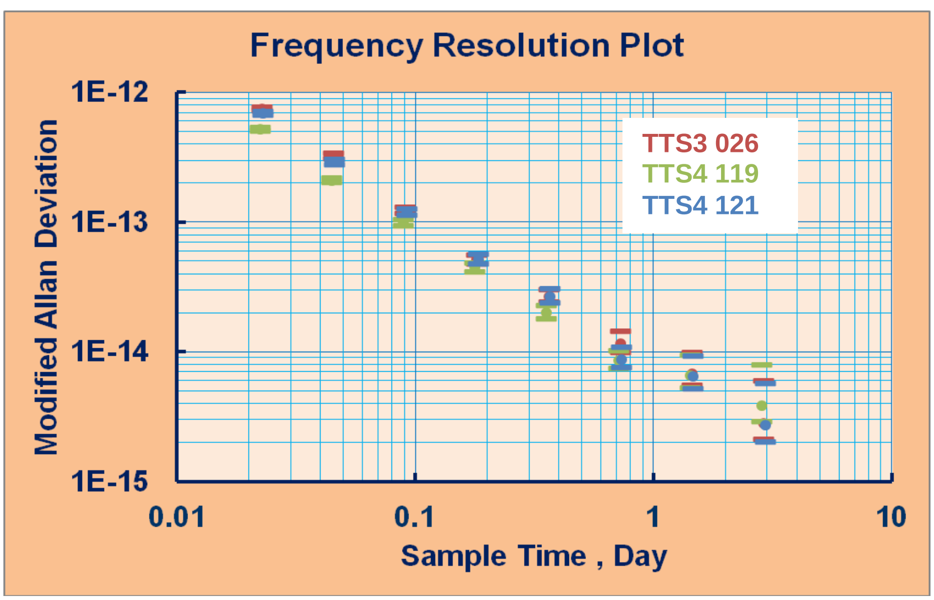

Figure 12. Mendeleevo-Khabarovsk time link frequency resolution by different receivers.

The next Figure 12 displays corresponding frequency resolution of the above -mentioned time links. This looks quite natural, that for a greater than 6000 km time link, one gets frequency resolution considerably worse than that for a short baseline, seen in Figures 6 and 9. There are a lot of sources of instability: propagation phenomena, broadcasted ephemeris, etc. Moreover, the data for time link frequency resolution referred to different time scales are partially deteriorated by time scale instability, at least for longer sample times.

CONCLUSIONS

In this work we have been investigated features and demonstrated potential and practical metrological performances of the new powerful time transfer instrument TTS4. We hope that such an instrument may be useful for all those time laboratories who deal with time transfer and GNSS time monitoring. During this work, manufacturers continuously produced and distributed new software versions which considerably improved performance of the instrument and we expect that these efforts will be continued.

ACKNOWLEDGEMENTS

P. Nogas, the TTS4 software developer whose cooperation and advice strongly helped in this work, is gratefully acknowledged.

REFERENCES

[1] *Time Transfer System 3 TTS – 3, www.piktime.com*

[2] W. Lewandowski and L. Tisserand, 2010, *"Relative characterization of GNSS receiver delays for GPS and GLONASS C/A codes in the L1 frequency band at the OP, SU, PTB and AOS,"* Bureau International des Poids et Mesures, Rapport BIPM-2010/04.

[3] D. W. Allan and C. Thomas, 1994, *"Technical Directives for Standardization of GPS Time Receiver Software to be implemented for improving the accuracy of GPS common-view time transfer,"* **Metrologia, Vol. 31**, 69-79.