State Scientific Center
of the Russian
Federation

VNIIFTRI

National Research Institute for
Physical-Technical and Radio Engineering Measurements

Effects of reference frequency stability to SLR measurements Errors

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National Research Institute for Physical-Technical and Radiotechnical Measurements (VNIIFTRI) has a working SLR station «Mendeleevo-1874» and SLR station «Irkutsk-1891» in the East-Siberian Branch of VNIIFTRI in the city of Irkutsk.

Calibration and metrological control of these stations is carried out with the involvement of the national standard of time and frequency as well as the national special standard of length.

Metrological support

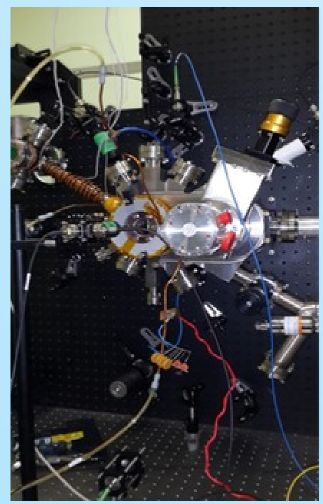
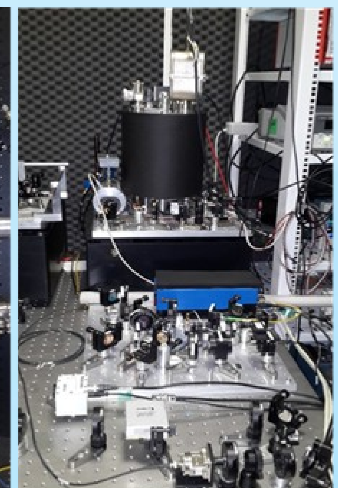
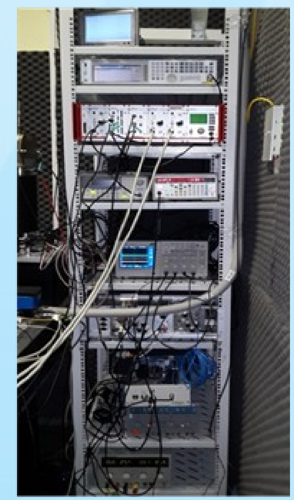
National time and frequency standard in Mendelevo UTC(SU);
National standard of length in Mendelevo;
Secondary time and frequency standard in Irkutsk city;



Auxiliary equipment

Mobile laboratory with mobile TWSTFT station and activ H-maser;
Fixed TWSTFT station in Mendeleevo;
Leica TDA 5005;
Precise gravimeters;
GPS/GLONASS receivers;
Local Geodetic Network;
and other…



At present, VNIIFTRI supports and improves 51 State primary standards, over 200 secondary and working standards and calibration rigs for various fields of measurement.

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Errors SLR-measurements associated with the par value of the reference frequency

$$\frac{\Delta R}{R} = -\frac{\Delta f}{f}$$

R – distance
f - reference frequency

Accounting for this component of the error becomes relevant in the transition to the millimeter and submillimeter accuracy of measurements

Errors SLR-measurements associated with time scale

Now error of time scale of most laser stations is 50 ... 200 ns.
Fixation point in time of measurement can be
Significantly greater amount ranging
up to values of a few microseconds.

Time of flight measurement error in a laser ranging station

$$T_{err} = R_{es} \pm (\Delta f_0 / f_0) T_{of} \pm T_{rerr1} \pm T_{rerr2} \pm S_{err}$$

$$R_{es} = \sqrt{\frac{D_{res}^{\ 2} + (S_{ts} T_{of})^2 + T_{rjt11}^{\ 2} + T_{rjt2}^{\ 2}}{N}}$$

$$T_{rerr} = \sqrt{\frac{E_{inp}^{\ 2} + E_{int}^{\ 2}}{I_{sr}}}$$

Terr – time of flight error;
Tof – time of flight;
Res – resolution;
df0/f0 – timebase (frequency) error;
Serr – systematic error;
Dres – device resolution;
Sts – short term stability;
Trerr1 – trigger error «start»;
Trerr2 – trigger error «stop»;
Trjt1 – trigger jitter «start»;
Trjt2 – trigger jitter «stop»;
Einp – input signal noise;
Eint – internal signal noise;
Isr – input slew rate

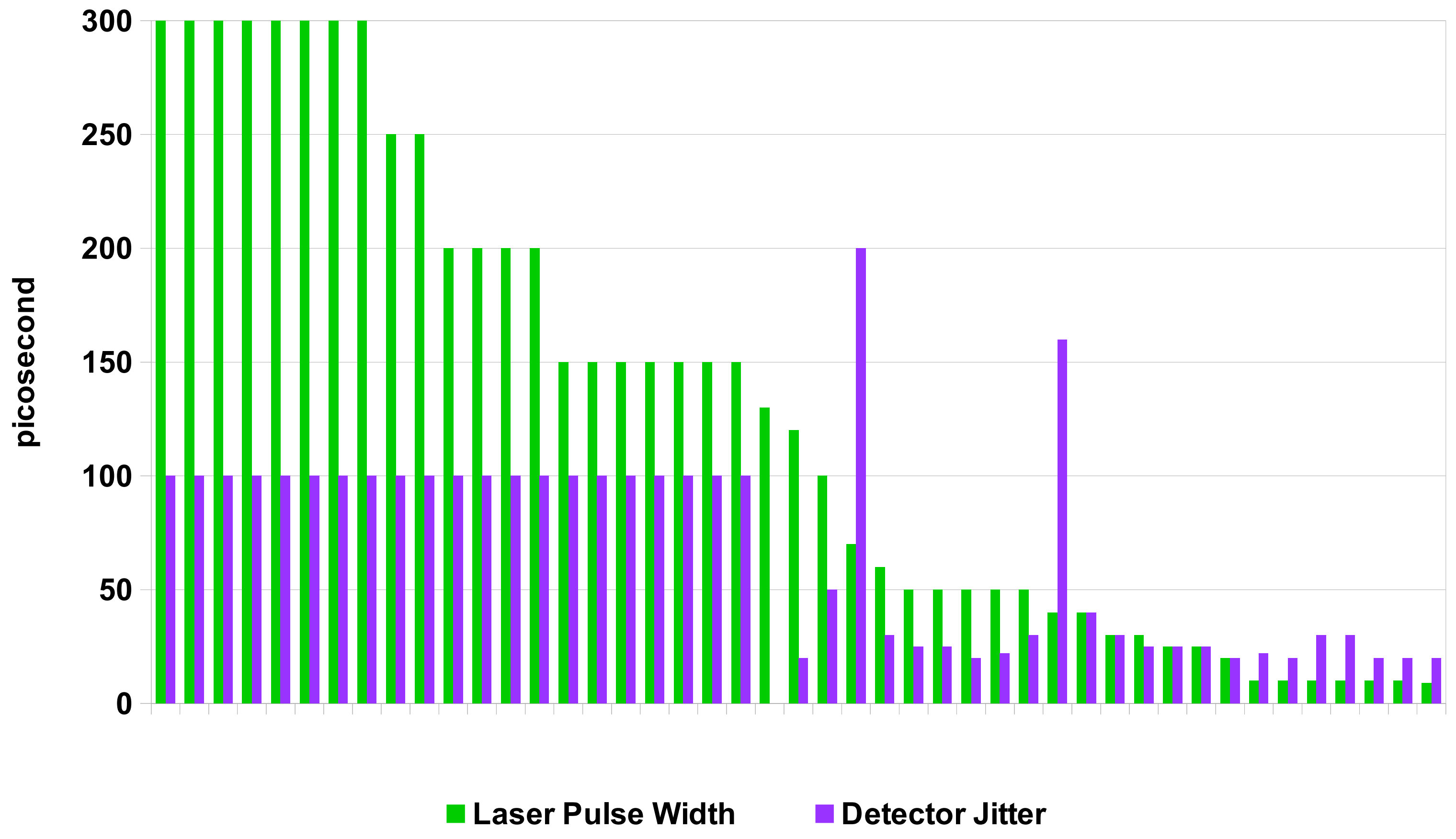
[Van Husson, Stewart Loyal]

Table : Influence of $\Delta f_0 / f_0$ on Range Measurement (all units in mm)
(Note: Maximum TOFs in milliseconds (ms) appear in the header row.)

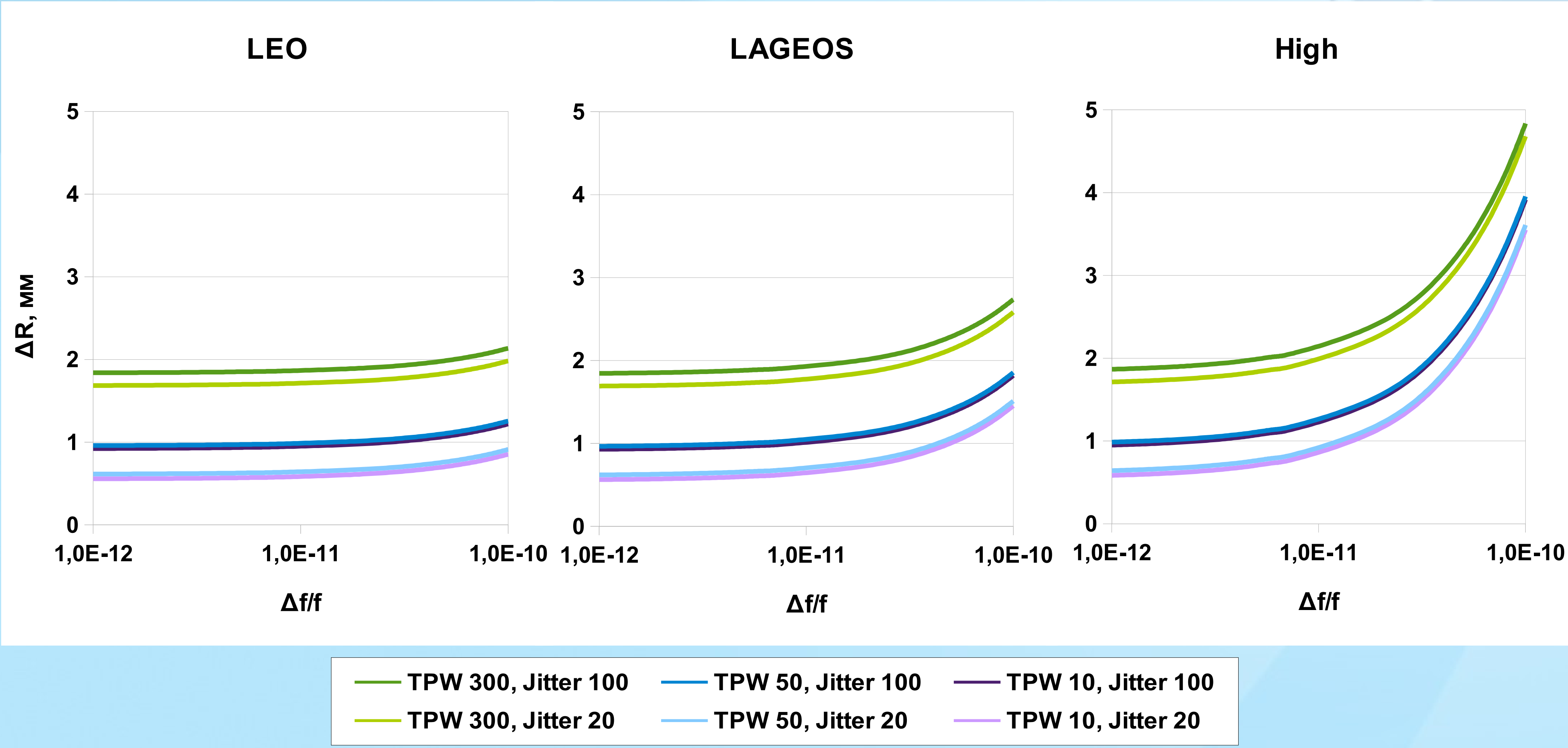
$\Delta f_0 / f_0$	LEO (25ms)	LAGEOS (60ms)	High (200ms)	Lunar (2500ms)	Mars (1,000,700ms)
1.E-07	374.741	899.377	3297.717	37474.057	15000000.000
1.E-08	37.474	89.938	329.772	3747.406	1500000.000
1.E-09	3.747	8.994	32.977	374.741	150000.000
1.E-10	0.375	0.899	3.298	37.474	15000.000
1.E-11	0.037	0.090	0.330	3.747	1500.000
1.E-12	0.004	0.009	0.033	0.375	150.000
1.E-13	0.000	0.001	0.003	0.037	15.000
1.E-14	0.000	0.000	0.000	0.004	1.500
1.E-15	0.000	0.000	0.000	0.000	0.150
1.E-16	0.000	0.000	0.000	0.000	0.015

Legend
>10mm
>1mm but <10mm
<1mm
<0.1mm

ILRS Network Stations



Possible accuracy of Normal Point



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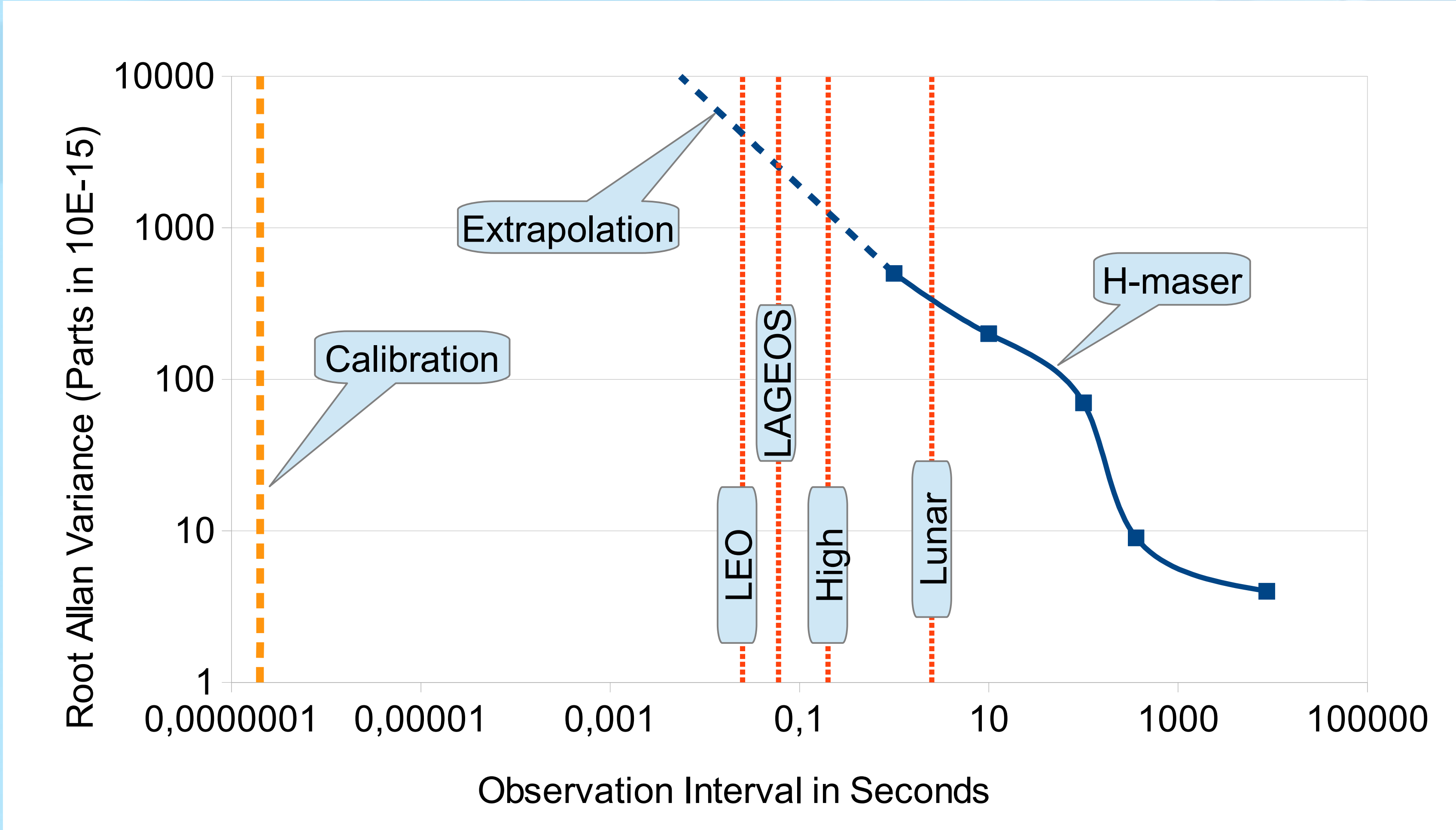
Root Allan Variance



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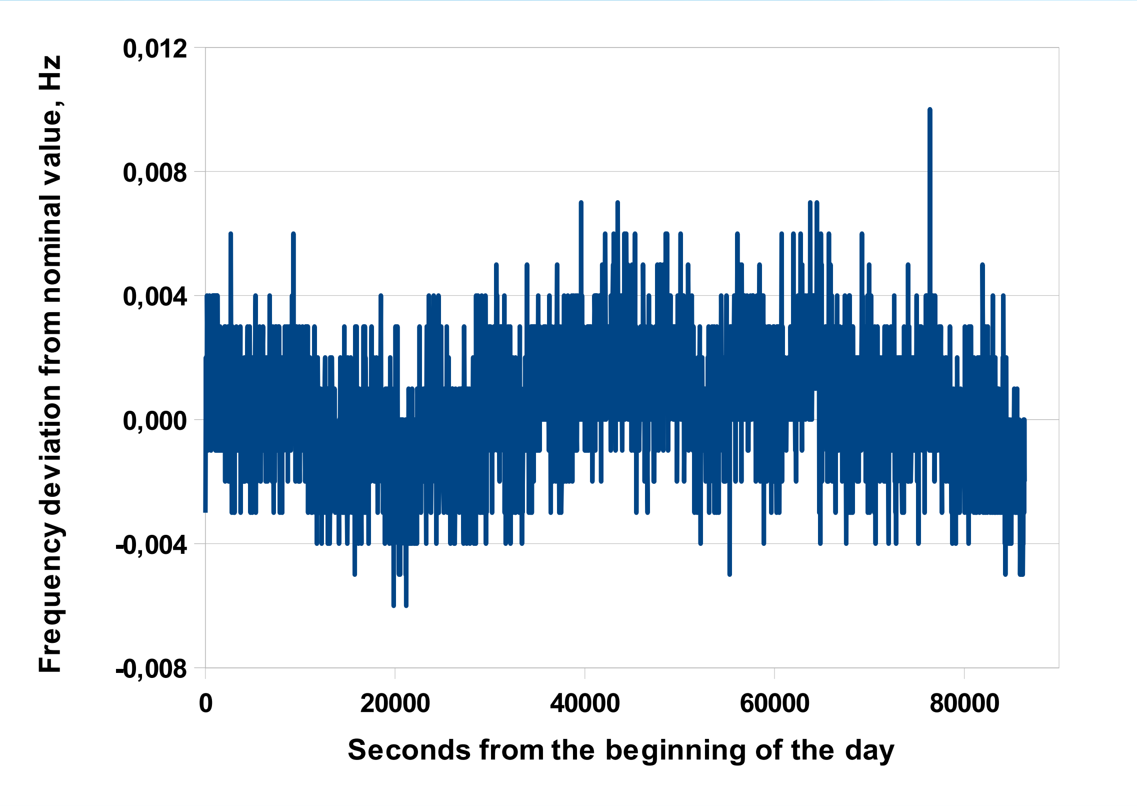
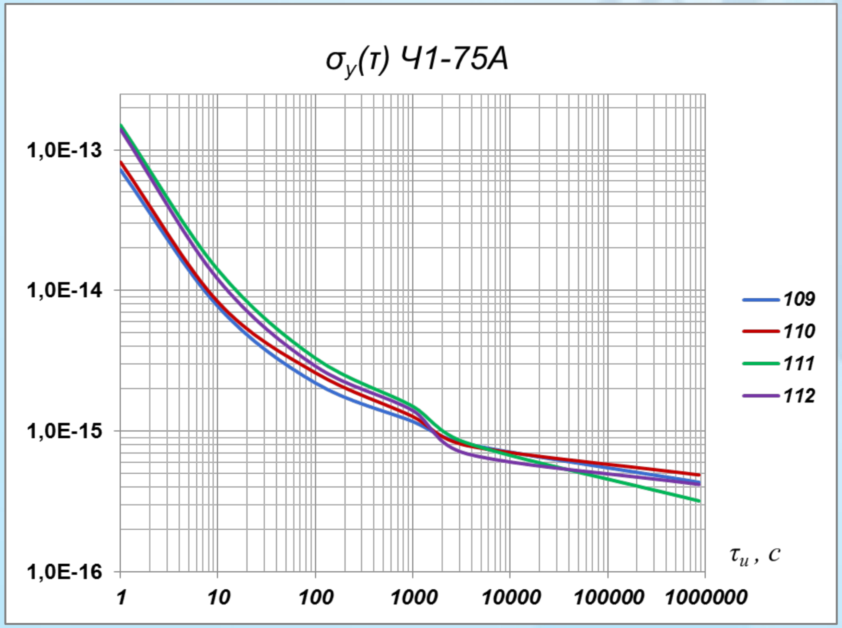
Frequency instability of hydrogen standards

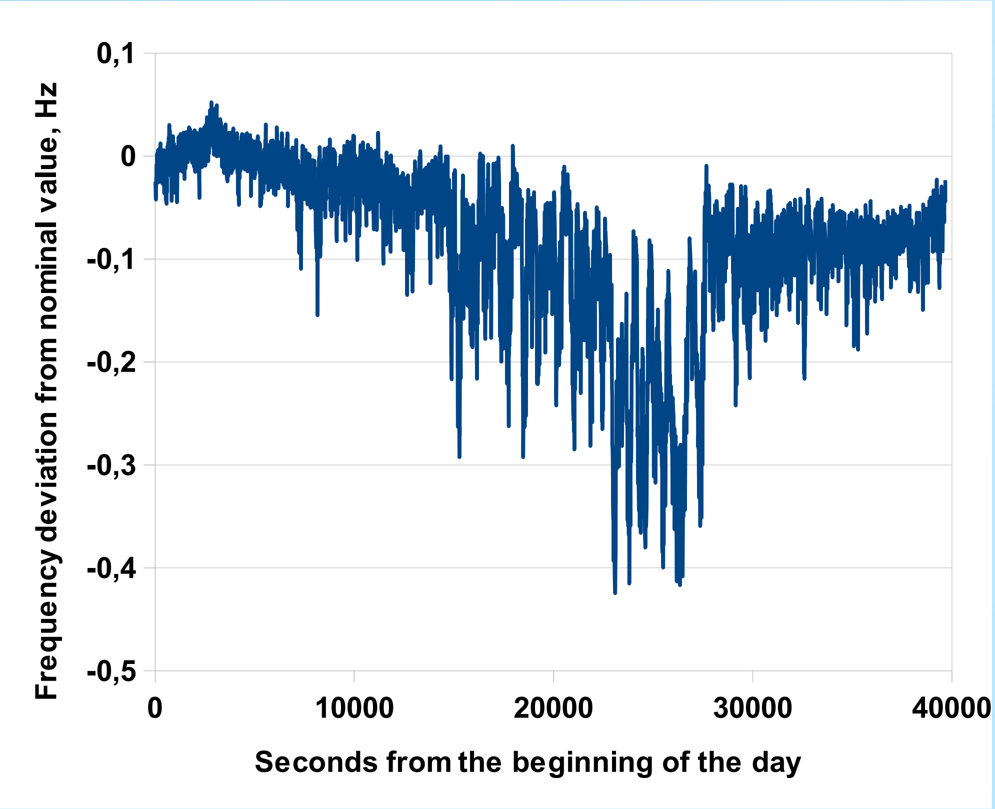


Instantant 10 MHz frequency variation of GNSS receiver within 24 hours, measured by means of the hydrogen generator. $\Delta f / f \approx$ 1,0E-10.

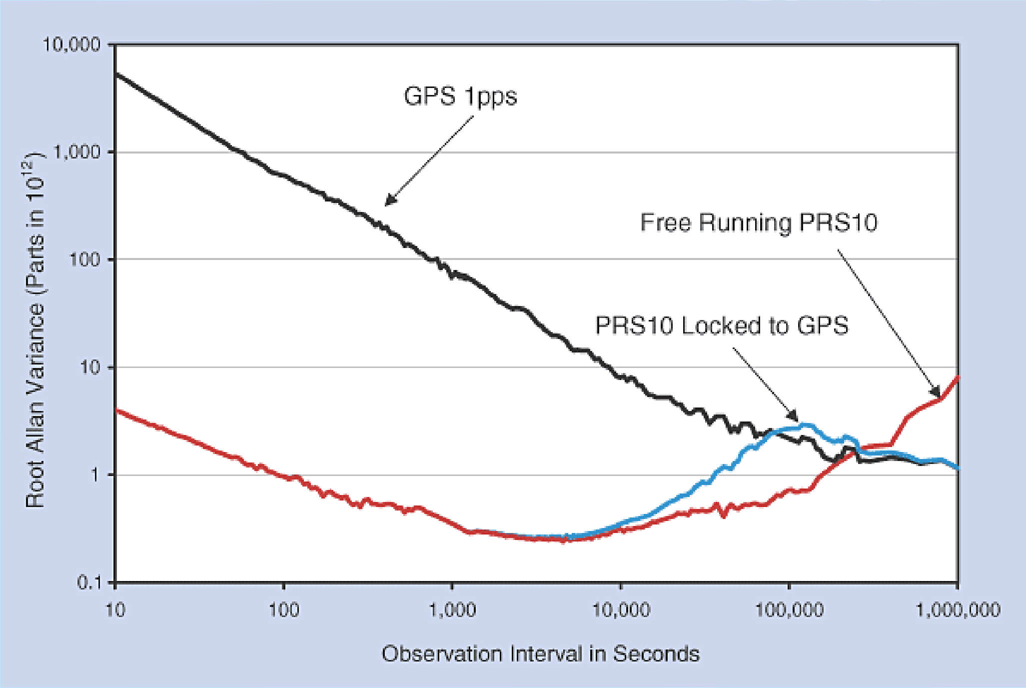


Frequency instability of hydrogen standards

Frequency instability of rubidium oscillator

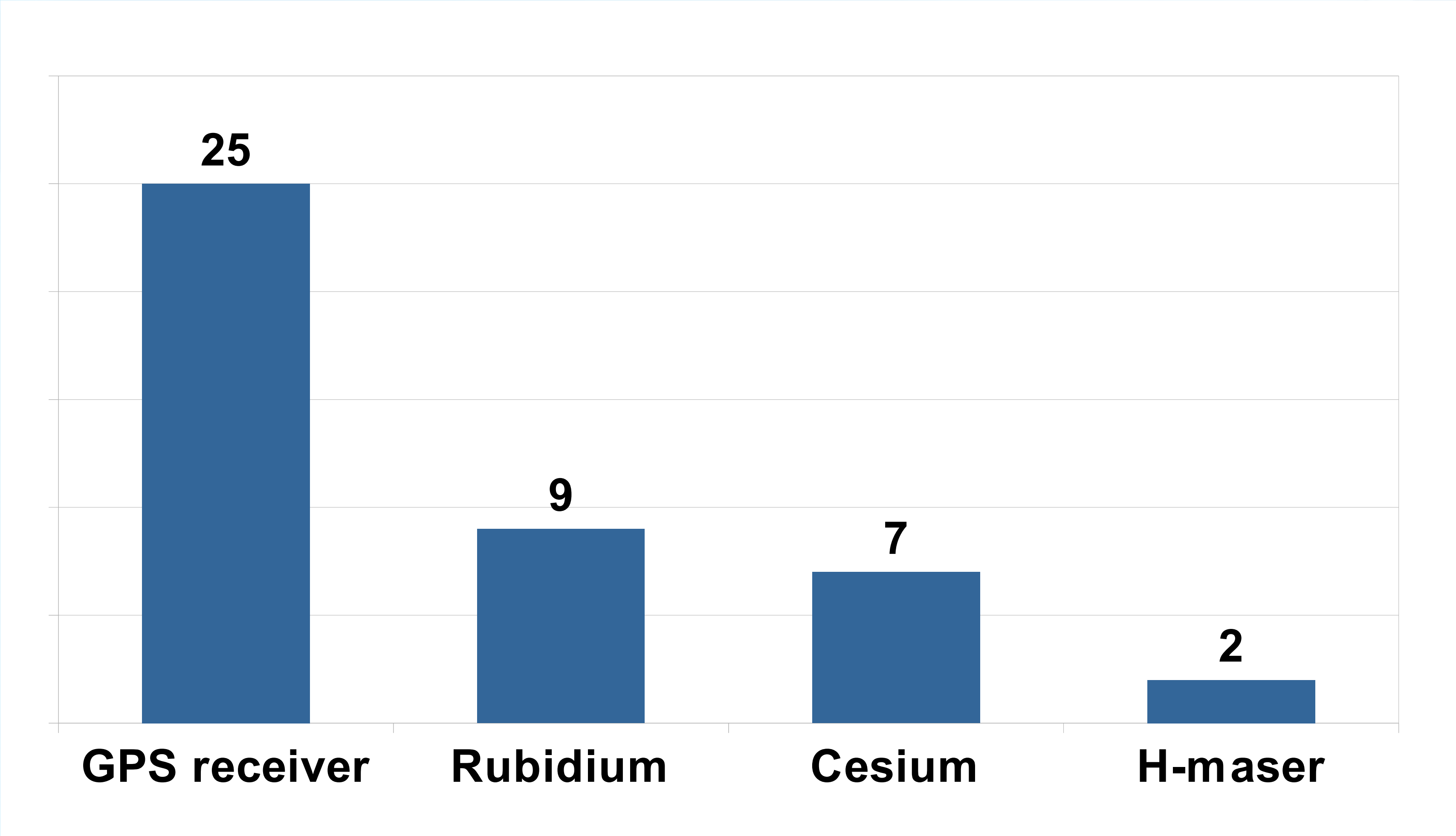


Instantant 10 MHz frequency variation of GNSS receiver within 12 hours, measured by means of the rubidium generator. $\Delta f/f \approx$ 1,0E-9.



Frequency instability of rubidium oscillator

ILRS Network Frequency Standard Types



Numbers of stations with different types of frequency standard types

Synchronization system of the reference frequencies of the laser station

Composition:
- 2 passive H-masers Ч1-1007
  df/f=5E-13, t=1s,
  df/f=4E-15, t=24h;
- GNSS Receiver GTR-51;
- Data server;
- NTP server;
- Comparison system;
- signal amplifiers and distributors.

Long-term frequency drift of the H - maser can be eliminated by snapping to a source with better long-term stability, such as a 1 pulse per second from a GNSS receiver.

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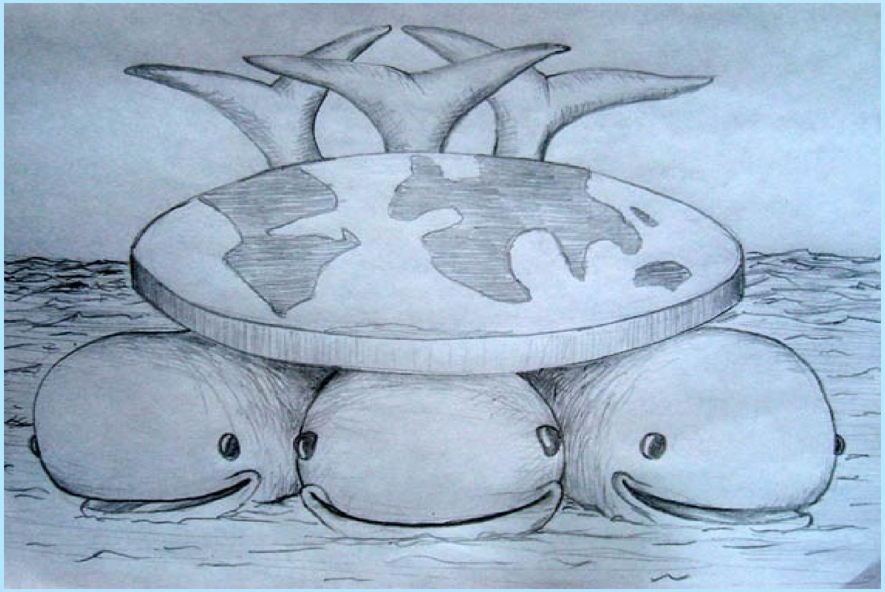
Conclusion

Modern requirements for the accuracy of laser ranging with an increase in the number of satellites, and therefore for the performance of stations, require improvements in the characteristics of short-term frequency stability.



Thanks!! ☺

Special gratitude to our colleagues, who participated in the discussion of the issues involved.