Active hydrogen masers established by Vremya-CH (Nizhny Novgorod)

The accuracy of time and frequency measurement is the basis for the development of the most important technologies in industry and science.

The state verification scheme for time and frequency measuring instruments includes the GET-1 State primary standard of unit of time, frequency and national time scale, which is used to transfer national time scale and frequency signals from the GET-1primary standard to the secondary and local reference standards, as well as to the time and frequency measuring instruments. Measurements are performing by means of comparisons using comparators, transported quantum clocks, as well as by the method of comparisons using the signals transmitted via communication channels and space navigation systems.

The equipment of all stages of the verification scheme includes highly stable frequency reference signal sources.

The frequency stability parameters of the reference source define the requirements for the measurement accuracy of subsequent elements: frequency and phase comparators, instruments of the time unit transmitting, distribution amplifiers, and consumer measuring equipment.

Thus, improving the level of metrology is a complex aid, and its solution should begin with improving the frequency stability of the reference source.

The accuracy of the reproducibility, keeping, and transmitting the signals of the national time and frequency primary standards are set at the level of ($10^{-17} \div 10^{-18}$) relative units for the frequency of reference signals and less than 100 picoseconds of time scale error.

Based on more than 30-years of experience, the team of Vremya-CH JSC developed active hydrogen masers with has the best in the world frequency stability characteristics of the output signal at the level of 6×10^{-14} for 1 s measurement interval of and 6×10^{-17} for long time intervals.

These technology achievements were realized in a new generation equipment of the GET-1 State primary standard of unit of time, frequency and national time scale of the Russian Federation.

The key aspects of the newly created technical solutions are:

- development of a new design of the hydrogen maser microwave cavity with a precision digital temperature control system;
- improvement of the atomic beam selection system;
- advanced technical solutions in the electronic components of the device using the low-noise elements;
- application of digital signal processing methods, which made it possible to reduce the temperature phase sensitivity by more than 5 times.

As a result of this work the maser parameters were significantly improved:

- frequency stability characteristics of the output signal reduced to $6x10^{-17}$ for long time intervals,
- temperature and magnetic sensitivity reached less than $3x10^{-16}/^{O}C$ and magnetic frequency shift less then $3x10^{-15}$/Oersted;
- phase noise spectrum purity of the output signals reduced to minus 130 dBm/ Hz at 1 Hz, and 160-170 dBm/ Hz at 10 kHz or more.

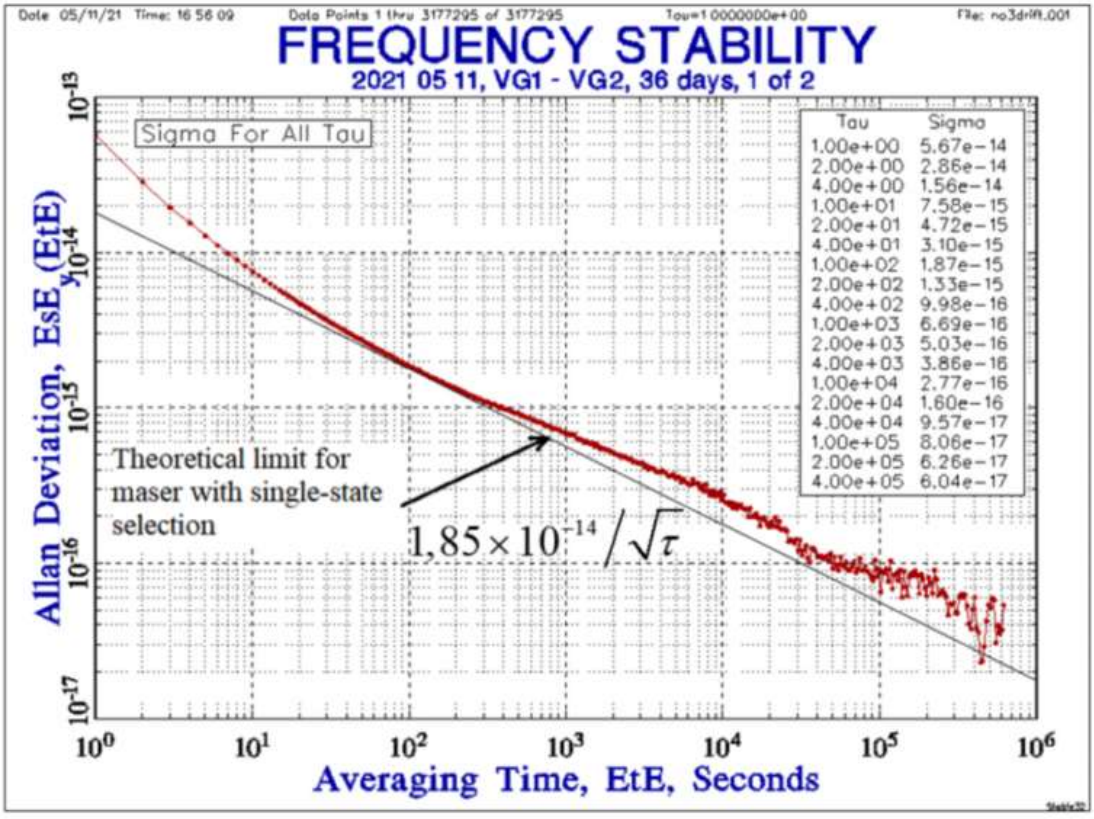
VCH-1003M (VCH-1003M option L) active hydrogen maser

The basis technology of the time keeping generating equipment of the national time scale of the Russian Federation

Bestseller on the world market, combines the best features and high reliability.

It is the main tool for atomic time scales of leading laboratories in Germany, France, China, Canada, India, etc.

VCH-2021 is a unique device, there the atomic beam double selected system was implemented, which allowed to obtain the excellent frequency stability characteristics.



VCH-2020 Portable Hydrogen Clock – portable active hydrogen maser time and frequency device. The main application is a high-precision time scales reference signals transmitting and comparison between of the geographically remote laboratories.
It is allowed the transportation by car in the switched-on state. The characteristics of the VCH-2020 are similar to those of the laboratory VCH-1003M hydrogen maser.
Time keeping error during transportation is less than 300 picoseconds per day.
Output signals:

- 5; 10; 100 MHz (sin), 1 V at 50 Ohm load;
- 1 pps (time scale) 2,5 V at 50 Ohm load.

The devices VCH-2020 and VCH-2021 have an optical output equipped with a phase distortion and delay compensator, which allows you to receive an active hydrogen maser quality signal at a distance of up to 70 km. The shift of the remote time scale relative to the maser output does not exceed 300 ps.