Drift compensation of hydrogen frequency standard output signal

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Frequency drift of the output signal of the hydrogen frequency standard was detected about 40 years ago, but so far this phenomenon has been poorly studied. In our previous work the physical model of frequency drift was proposed. The model is based on the solution of the hydrogen maser differential equations in a «steady-state» approximation and research of an asymptotics of relaxation processes in quantum system[1]. Frequency evolution of a quantum system is described by the following equation:

$$\Delta\omega_{sys}(t) = \left(\frac{1}{T_2(t)} + \frac{K\omega_c}{2} \frac{T_1(t)T_2(t)I\ (t)}{1+T_1(t)T_2(t)b_R(t)^2} \right) \times \sin(\vartheta) \quad ,$$

where ω_c – cavity frequency, T_1 , T_2 – longitudinal and transverse relaxation time, ϑ – difference between oscillation phases of the microwave field and the induced magnetic moment of atomic ensemble, I – magnitude of the beam flux, b_R – Rabi frequency, t – time, K – constant. It is supposed that the model will allow to predict the evolution of a hydrogen maser frequency based on monitoring of the maser physical parameters (amplitude generation, magnitude of the hydrogen beam flux, the quality factor of the line).

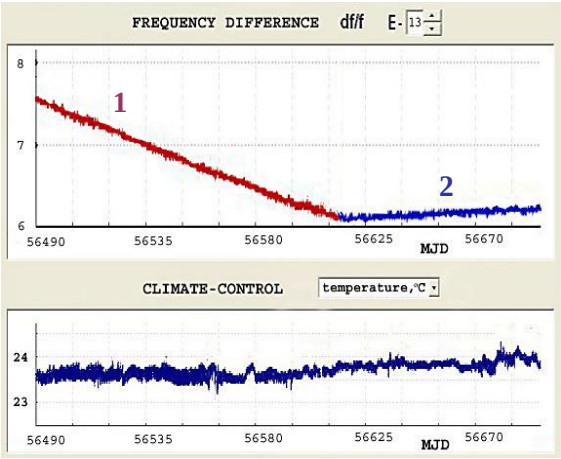

Fig.1. Evolution of output signal frequency of CH-75B: 1 – drift at manufacturing; 2 – at physical drift compensation.

An important task is to minimize or compensate frequency drift. Some time ago the idea of drift compensation was proposed. For this purpose hydrogen maser microwave resonator was used. It was proposed that microwave resonator frequency was being detuned specially in the opposite direction[2]. On the other hand we have proposed a method that uses a built-in crystal oscillator frequency change. A frequency synthesizer of standard control the voltage controlled oscillator frequency according to frequency forecasting. This method is implemented in a new model of the frequency hydrogen standard CH1-75B. The CH1-75B has a special built-in unit to compensate frequency drift. This unit adjusts the output frequency of the frequency standard based on a linear model of the drift. The tested standard had frequency drift of 1.0×10^{-15}/day at manufacturing, then physical compensation was switched on and drift decreased 5 times. In the plot the frequency evolution before and after the beginning of compensator unit operation is presented. In the paper two methods are compared.

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[1] Vasilyev V. I., Gavrilov V. V., Gorelov A. G. Physics of systematic frequency drift of active hydrogen masers with autonomous cavity auto tuning.// – Proc. of the joint conference IFCS-EFTF, 2013, pp. 241-244.

[2] Mendel E. E., Stover D. W. Microprocessor for the NR series of hydrogen maser frequency standards.// – Proc. of the 37th Annual FCS, 1983, pp. 27-31.