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"METROLOGY OF TIME AND SPACE"

DESIGN OF THE ACTIVE HYDROGEN MASER NEW MODEL (VCH-1003M) USING MICROWAVE CAVITY FREQUENCY SWITCHING TECHNIQUE FOR CAVITY AUTO TUNING

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Hydrogen masers main applications:

1. Fundamental physics;
2. Relativistic theories;
3. Data transfer;
4. Astronomy and VLBI;
5. **Time keeping**

Five principal perturbation factors to affect the long-term stability:

1. Second-order Doppler frequency shift;

2. Magnetic-field-dependent frequency shift;

3. Spin-exchange frequency shift;

4. Wall shift;

5. Cavity pulling

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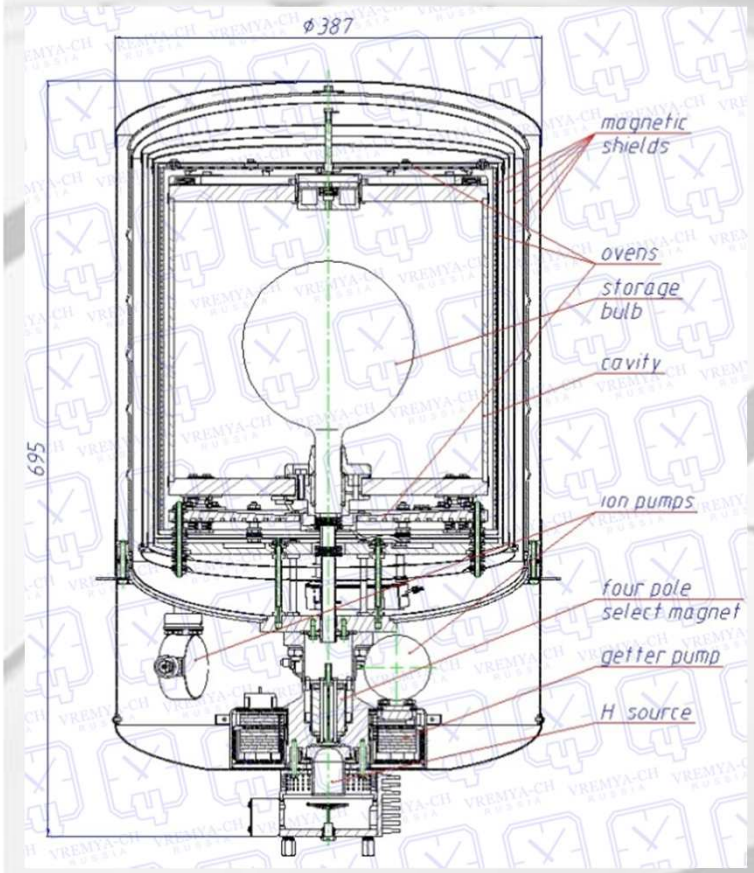
Physics package design



Main features of the VCH-1003M:

- two varactors for cavity tuning;

-high-precision digital control of the maser cavity ovens with temperature stability of the order 10^{-4} ºC;

-cavity has a very low thermal expansion less than 2×10^{-7}/ºC. It allows the maser temperature sensitivity less than 2×10^{-14}/ºC to be obtained;

-five layer magnetic shields provide low magnetic sensitivity $1\times10^{-14}/10^{-4}$T;

- light and compact vacuum system consisting of getter and two ion pumps permits to get the vacuum better than 10^{-6} Pa.

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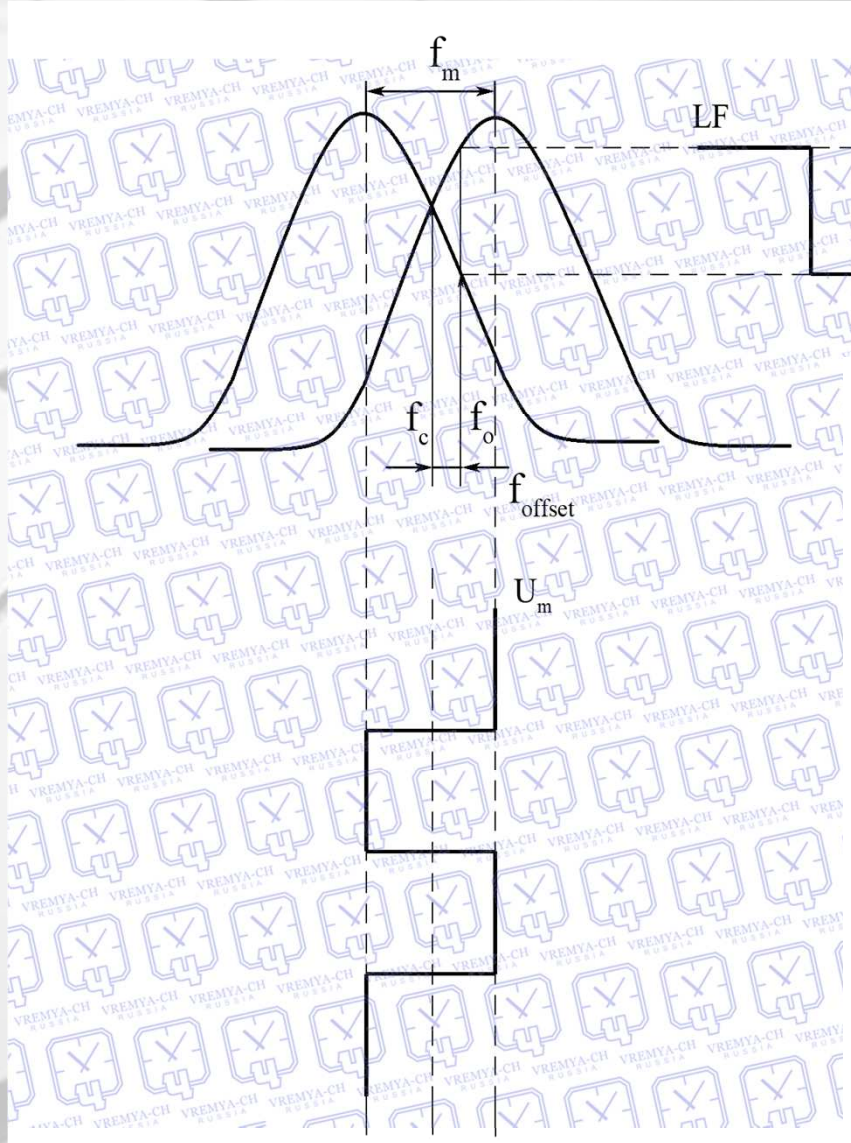
Basic principles of the cavity frequency switching technique operation



f_o – hydrogen emission line frequency is used as a reference for cavity tuning;

f_c – the average cavity frequency;

U_m – two-level square wave modulating voltage switches cavity frequencies with the difference f_m;

f_{offset} – frequency offset between hydrogen emission line frequency f_o and the average cavity frequency f_c;

LF – low frequency modulation voltage in the maser output signal if there is the frequency offset.

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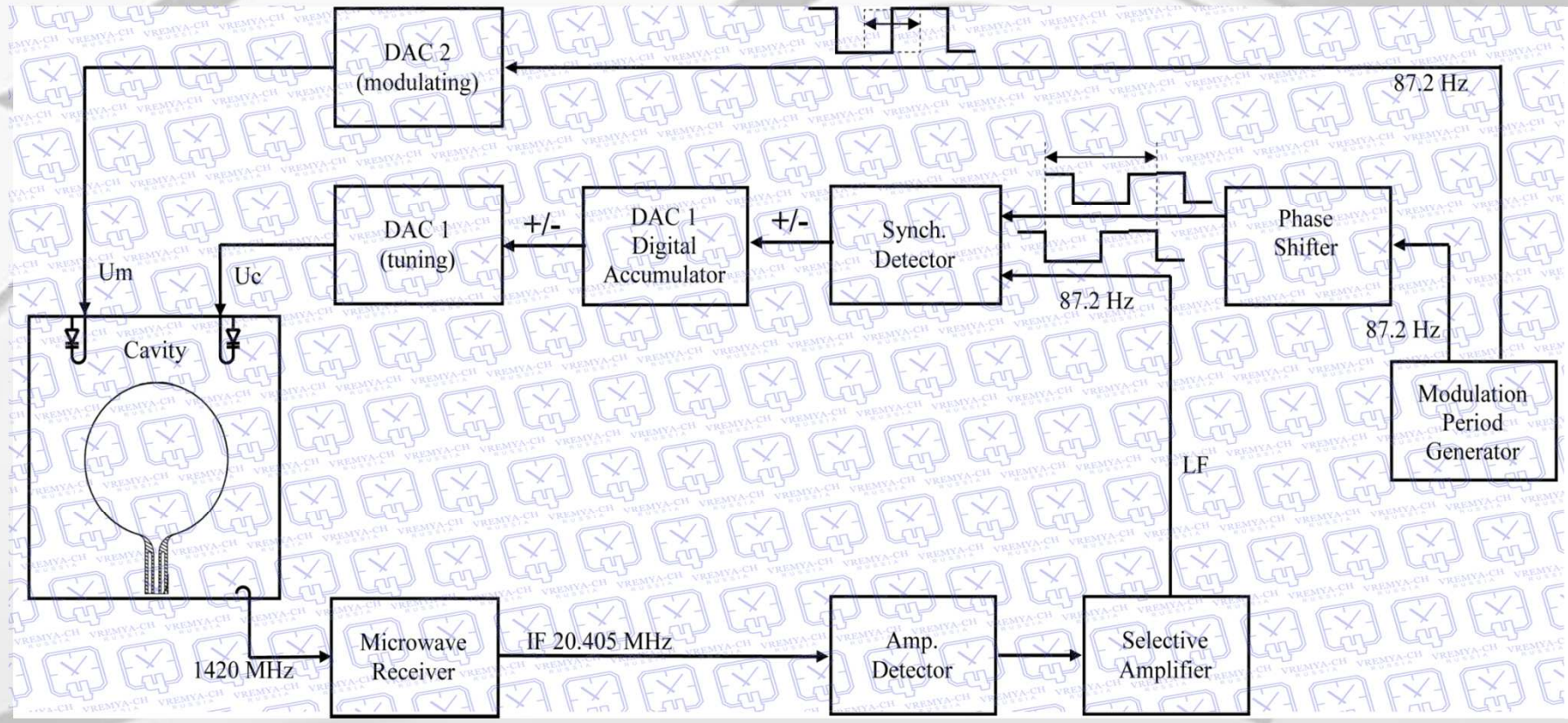
Schematic diagram of the cavity tuning system based on the cavity frequency switching method



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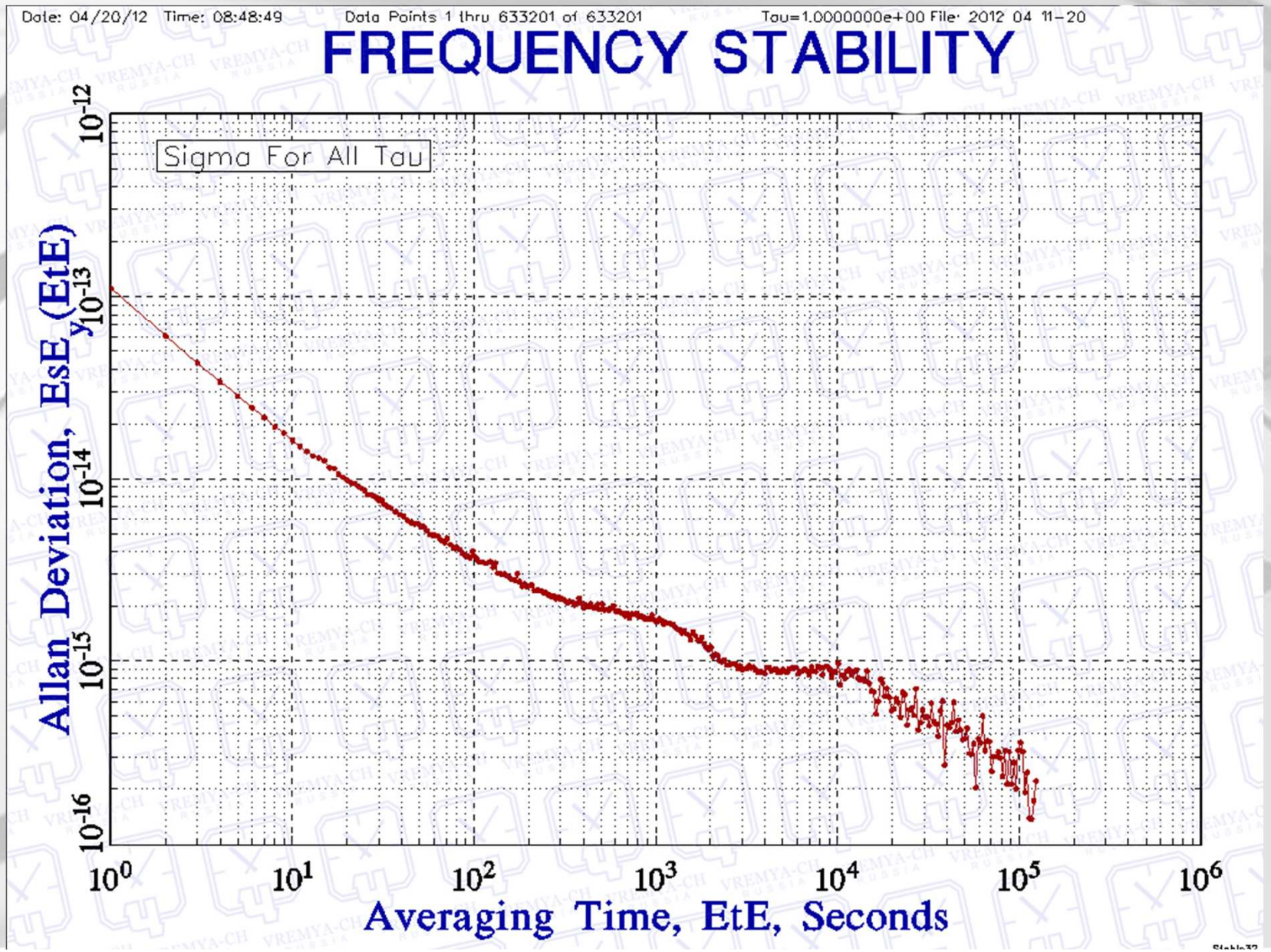
Hydrogen maser stability (Allan deviation)



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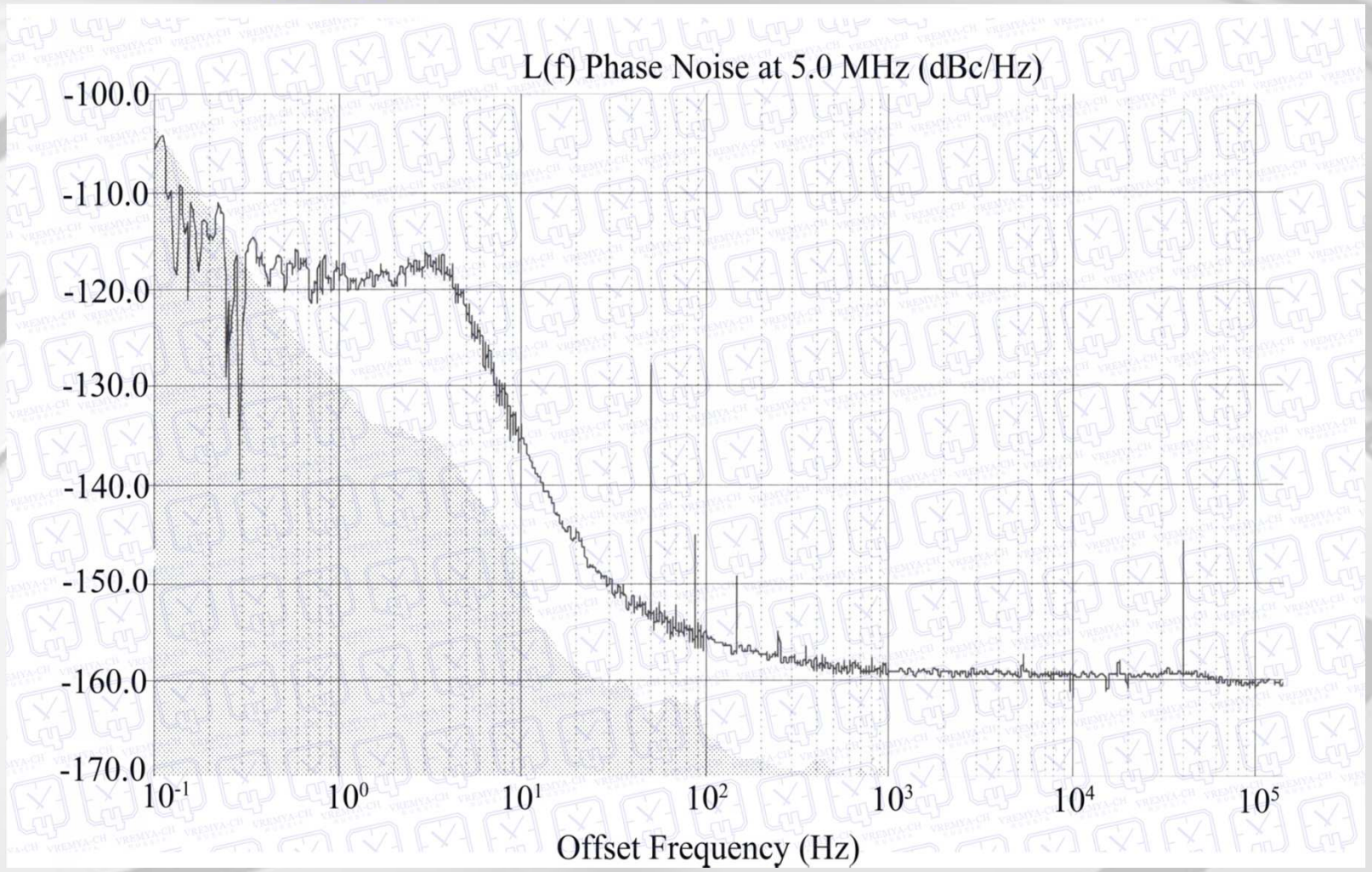
Phase noise of output signals



Modulation frequency's spurious components are suppressed up to the -145dBc level

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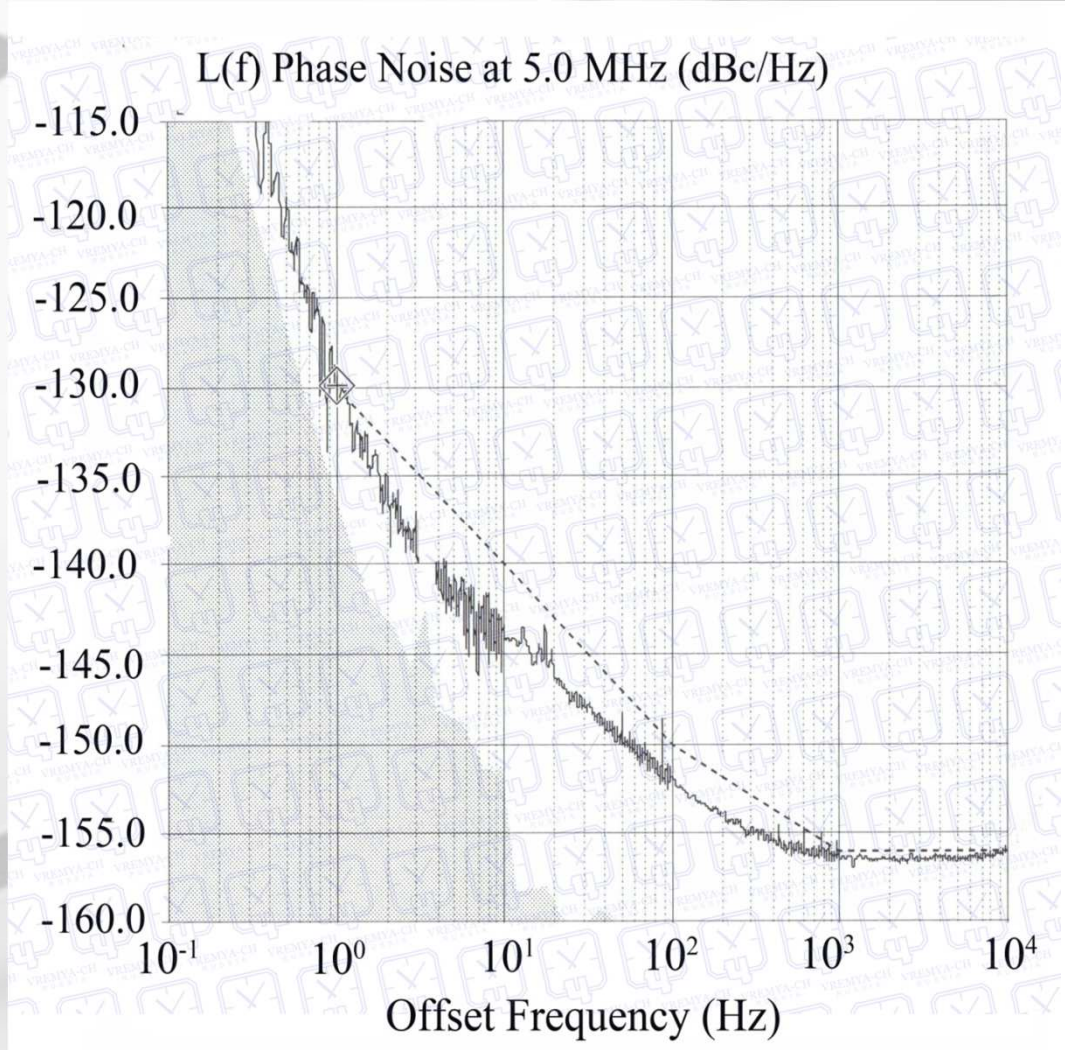
Phase noise in case low noise crystal oscillator is used



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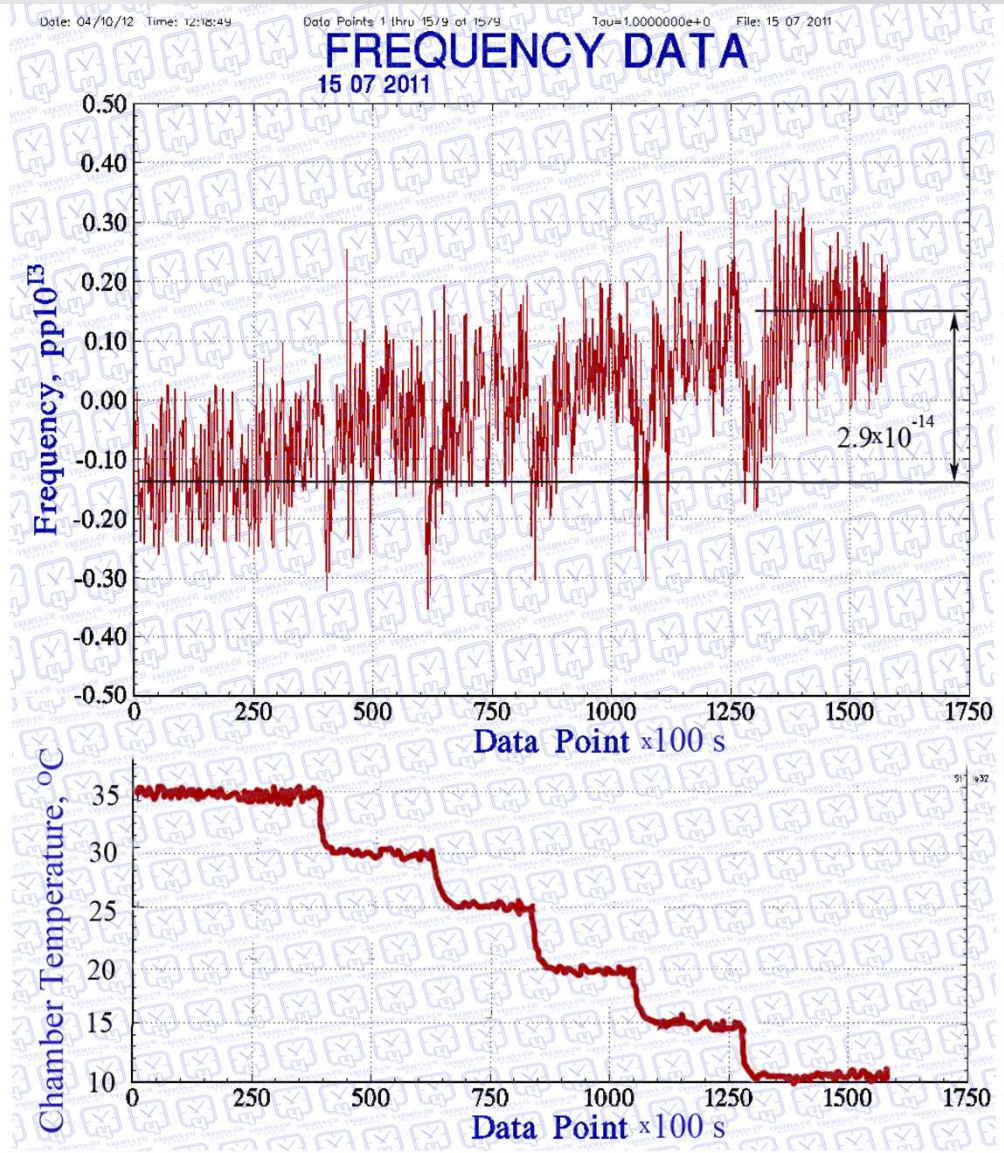
Temperature sensitivity



Typical temperature sensitivity of the maser (1.2×10^{-15}/°C)

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Hydrogen maser under magnetic test

Magnetic sensitivity less than $1 \times 10^{-14}/10^{-4}$T

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Active Hydrogen Maser VCH-1003M

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CONCLUSION

- Cavity tuning system operation does not worsen the maser output signal short-term stability (at the averaging time τ=1s - 10^3s) and the phase noise;
- Frequency stability about (3÷5) x $l0^{-16}$ at the averaging time $\tau \geq 10^5$s has been reached;
- High long-term stability and predictable maser frequency behavior enable the masers to be efficiently used in precision time keeping applications;