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
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 $10^{-4}$ °C;
- cavity has a very low thermal expansion less than $2\times10^{-7}$/°C. It allows the maser temperature sensitivity less than $2\times10^{-14}$/°C 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.
Basic principles of the cavity frequency switching technique operation

\( f_0 \) – 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 \( f_m \);
\( f_{\text{offset}} \) – frequency offset between hydrogen emission line frequency \( f_0 \) and the average cavity frequency \( f_c \);
\( LF \) – low frequency modulation voltage in the maser output signal if there is the frequency offset.
Schematic diagram of the cavity tuning system based on the cavity frequency switching method
Hydrogen maser stability
(Allan deviation)
Phase noise of output signals

Modulation frequency’s spurious components are suppressed up to the -145dBc level
Phase noise in case low noise crystal oscillator is used
Temperature sensitivity

Typical temperature sensitivity of the maser (1.2 × 10^{-15}/°C)
Magnetic sensitivity less than $1 \times 10^{-14}/10^{-4}$T

Hydrogen maser under magnetic test
Active Hydrogen Maser VCH-1003M
CONCLUSION

• Cavity tuning system operation does not worsen the maser output signal short-term stability (at the averaging time $\tau=1s - 10^3s$) and the phase noise;

• Frequency stability about $(3\div5) \times 10^{-16}$ at the averaging time $\tau \geq 10^5s$ has been reached;

• High long-term stability and predictable maser frequency behavior enable the masers to be efficiently used in precision time keeping applications;