AEROSPACE

ATOMIC CLOCKS AND PRECISION TIMEKEEPING LABORATORY

Atomic clocks provide stable timekeeping essential for applications like position, navigation, and timing (PNT) systems, communications, signals intelligence, and geolocation. Enhanced clock performance supports longer autonomy from ground stations, while proliferated constellations require precision timekeeping solutions that are highly manufacturable and low in size, weight, and power (SWaP). Crosslinked constellations also enable new opportunities for space-based clock ensembles and time scales. The Aerospace Corporation leverages specialized labs to monitor clock performance, assess components, and test ensemble schemes and algorithms.

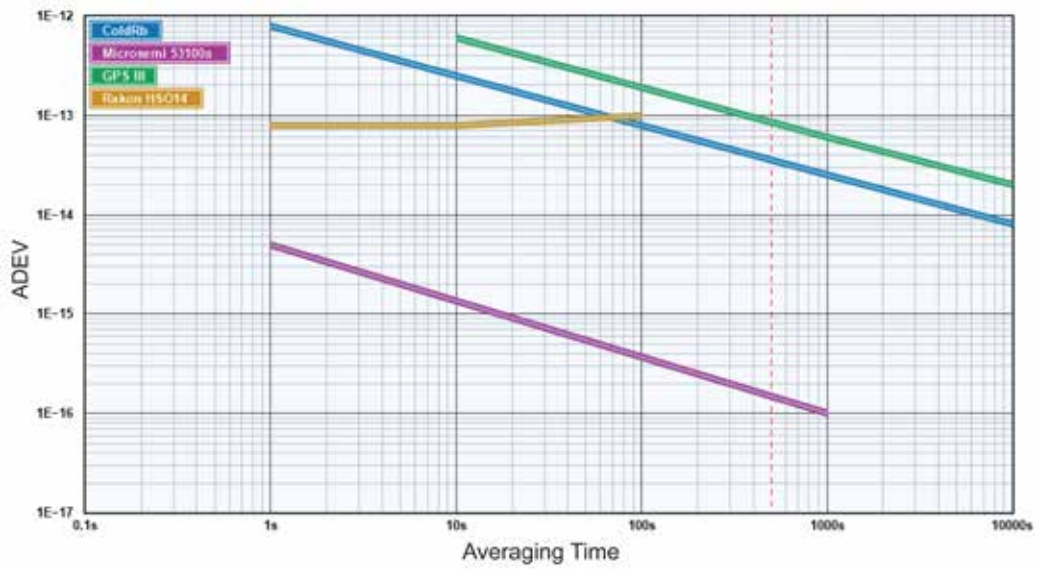
ADEV Measurements

Measurements available (5 MHz or 10 MHz signal):

- ADEV, MDEV, HDEV, TDEV, MTIE
- 3-cornered hat
- Phase noise
- Dynamic ADEV

References

- SpectraDynamics cold rubidium clock with ADEV 8e-13 @ 1s
- Hydrogen maser
- GPS
- Rakon HSO14



Example Allan deviation (ADEV) performance of each of the references. The Rakon crystal oscillator is best for low averaging time measurements while the cRb and GPS references are best for comparing against other types of atomic clocks or when long-term performance needs to be measured. The Microsemi 53100a is the noise floor of the measurement system and is the limit of the best performance measurable.

Acronym Definitions

- ADEV Allan deviation
- MDEV modified Allan deviation
- MTIE maximum time interval error
- HDEV Hadamard deviation
- TDEV timing deviation
- WFM white frequency modulation (noise)
- RWFM random-walk frequency modulation (noise)
- VCXO voltage-controlled crystal oscillator
- SWaP size, weight and power
- GPS Global Positioning System
- cRb cold rubidium
- Rb87 rubidium-87
- Cs cesium
- He helium
- N_2 nitrogen (molecule)
- Kr krypton
- Ar argon
- Ne neon
- Xe xenon
- RAFS Rubidium Atomic Frequency Standard
- RF radio frequency

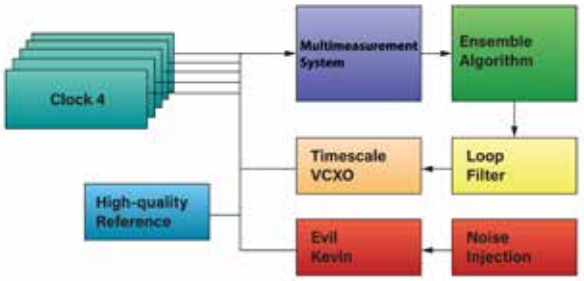
Thermal Vacuum (Thermovac) Chambers for Flight Environment Simulation

Our thermovac chambers are able to test clocks in space-like conditions with pressures down to 0.1 mTorr. Temperatures can be varied between –40°C to 200°C. Gas, such as helium, may be introduced to precise partial pressures for permeation experiments.

Left: The thermovac chamber. Right: Example setup of using a GPS RAFS in the thermovac chamber.

Clock Ensemble Testbed

We can test your clock ensembling algorithm! Our setup has five PRS10s monitored by a multimeasurement system. Various clock noise can be added to a clock, including frequency jumps, increased WFM and RWFM.



Left: The PRS10s that constitute the ensemble. Right: Block diagram of testbed config. Clocks are input to the multimeasurement system with the clock called “Evil Kevin,” the recipient of the emulated noise types.

Warm Vapor Atomic Clock Component Evaluation

Evaluation of submodules:

› Photonic integrated circuits
› Physics package
› Crystal oscillator
› Microwave cavity (S11)
› Magnetic field coils

Can be evaluated either in testbed clock or in isolation. Measurements of phase noise (5 MHz–10 MHz), sensitivity coefficients, light level stability and polarization purity/stability.

Vapor Cell Pressure Measurements

In Rb87 cells, we can measure pressures of:

› He, Ne, Ar, Kr, Xe and N_2

In Cs cells we can measure pressures of:

› Ne, Ar and N_2

Verify the buffer gas of Rb87 or Cs vapor cell using optical and RF measurements.

The Aerospace Corporation

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The Aerospace Corporation | 14745 Lee Road, Chantilly, VA 20151 USA | www.aerospace.org