Chip Scale Atomic Clocks Sources

Motivations

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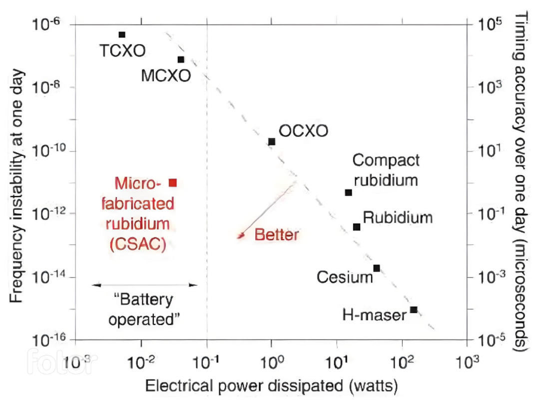
R&D direction

Program initiated in the early 2000s, funded by DARPA in collaboration with NIST, having the goal of developing an **ultra-miniaturized, low-power, atomic time and frequency reference units**.



Temperature sensitivity, long-term frequency aging, and turn-on to turn-on are better than traditional MEMS based clocks (but still are limiting factors).

Applications

Most important applications are related to **GNSS** (Global Navigation Satellite System).

Atomically precise timebases for portable, battery-operated GPS receivers allow for improved resistance to jamming and interference, faster acquisition time, and more reliable receiver operation.

Other applications include:

- Defense applications (i.e. UAVs)
- Telecommunications (i.e. next generation 5G networks)
- Space experiments (i.e. SPHERES project)
- Underwater oil and mineral exploration (through reflection seismology)

Outline for the project

Aim for this project is to give an overview of the commercially available CSACs.

The project will be divided into the following sections:

- **Working principles**: what's the physics behind the CSACs[1]
- **Technology comparison**: what are the performances of the different CSACs[2]
- **Applications**: what's the role of the CSACs in the different applications
- **Future developments**: what are the future perspectives for the CSACs

Our main focus will be on the Physics Packages (core), disregarding both the Local Oscillator and the Control Electronics.

[1] In order to better understand the innovation behind the CSACs, we will also give an overview of the table-size atomic clocks.

[2] We will also compare the CSACs with the traditional MEMS based clocks and table-size atomic clocks.

Extra slides

Atomic clocks comparison

Figure 1: Microsemi MHM 2020

Figure 2: Microsemi 5071A

Figure 3: Spectratime iSpace RAFS

Figure 4: Microsemi SA45s

Vendor	Product	Type	ADEV (1 s)	Aging (month)	Tmin (°C)	Tmax (°C)	Tempco	Power (W)	Weight (kg)	Size (cm^3)
Microsemi	MHM 2020	Maser	8,00E-14	9,00E-15				75,00	246,000	374072
Microsemi	5071A	CBT	5,00E-12		0	55		50,00	30,000	29700
Spectratime	iSpace RAFS	Space Rb	3,00E-12	8,30E-12	-5	10		35,00	3,400	3224
Microsemi	SA45.s	CSAC	3,00E-10	9,00E-10	-10	70	1,00E-09	0,12	0,035	17

Table 1: Key parameters

GNSS (Trilateration)

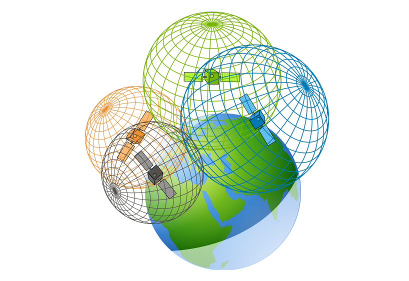


Figure 5: GPS trilateration

Basic math involved in trilateration:

$$\Delta d_i = c \cdot \Delta t = c \cdot (t_{\text{sat}} - t_{\text{rcvr}})$$

Our system of equations has 4 unknowns:

$$\underbrace{d_1, d_2, d_3, \Delta t}_{\text{4 Unknowns requires 4 satellites}}$$

Final position strongly depends on Δt.

Because of better holdover capabilities, the use of a CSAC in the receiver allows to eliminate the need for the 4th satellite after the first clock calibration.

A more accurate frequency of the receiver clock allows for a faster GNSS codes search and indeed a lower power consumption.

DARPA.
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Time for a better receiver: Chip-scale atomic frequency references.
(18), 2007-11-01 2007.

B. L. S. Marlow and D. R. Scherer.
A review of commercial and emerging atomic frequency standards.
IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, 68(6):2007–2022, 2021.

Microchip.
Microchip technology inc. (website).
https://www.microsemi.com/.

Questions?

Thank you!