Report of the TC Time and Frequency

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Time and Frequency

Contents

- TC-TF meeting and T&F strategy
- EMRP Projects and future optical redefinition of the second
- Time scale generation with low uncertainty based on BIPM and EURAMET projects activity

TC-TF Meeting

EURAMET TC-TF 2015 Meeting was at BEV on March

Main Subjects:

- EURAMET TF projects,
  - Time interval comparison
  - GNSS receiver calibrations and performance monitoring
  - Time Transfer using optical fiber links
- EMRP projects
- New projects
- **EURAMET TC-TF 2016 Meeting plan in MIKES on March**

TC-TF Meeting

TC-TF 2015 delegates

STRATEGY

The development of accurate ground atomic clocks

Target accuracy: from 10^{-14} - 10^{-15} to 10^{-17} - 10^{-18}

Space applications of atomic clocks and time-frequency metrology

Target accuracy of clocks on space $1x10^{-16}$ - $1x10^{-17}$ for next 10 years.

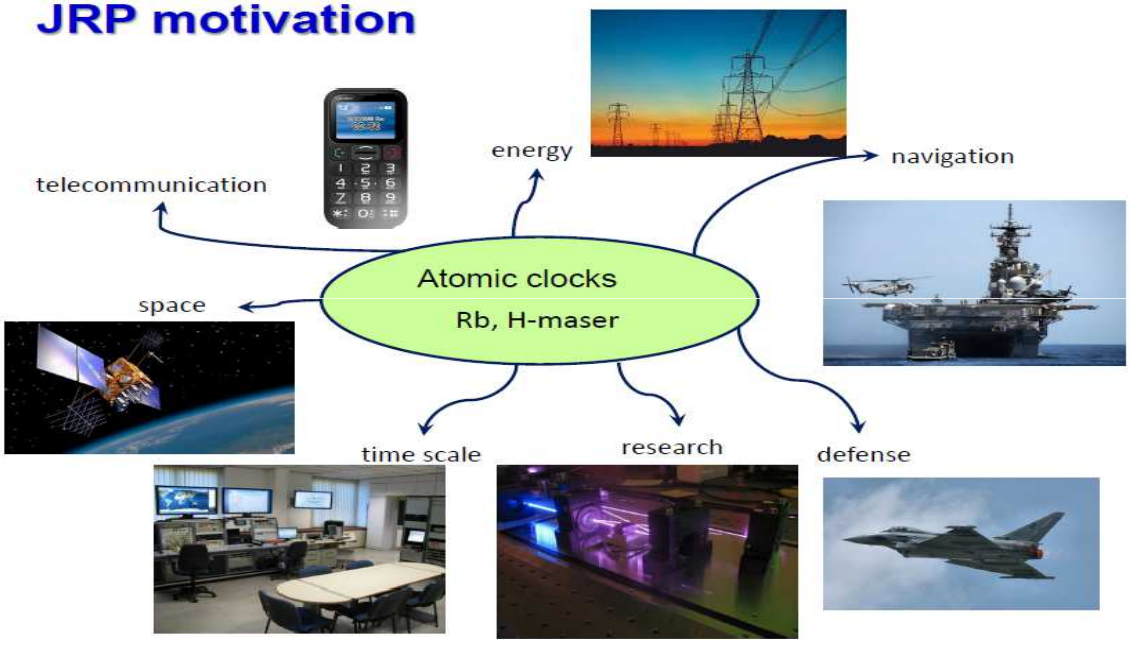
Time and frequency dissemination and comparison

In ground $<10^{-18}$ and <0.1ns; In Space $<10^{-16}$ and <0.1ns

Accurate time scale generation and traceability (from 7ns to <2 ns)

Impacts: New second, Gravity wave detection, fundamental constant, gas detection, Space, Navigation, Communication

JRP motivation



STRATEGY and ACTIVITY

The development of accurate ground atomic clocks

Target accuracy: from 10^{-14} - 10^{-15} to 10^{-17} - 10^{-18}

EMPIR, SRT-s16, Optical Clocks with 10^{-18} uncertainty

Time and frequency dissemination and comparison

In ground <10^{-18} and <0.1ns; In Space <10^{-16} and <0.1ns

EMPIR, SRT-s15, Optical Frequency Transfer – a European Network

Accurate time scale generation and traceability (from 7ns to <2 ns)

EURAMET, TC-TF, GNSS Comparison and Cable Delay Measurement

EMPIR, SRT-r05, International traceability for T&F measurements

EMRP Projects

SIB04, High-accuracy optical clocks with trapped ions

SIB55, International timescales with optical clocks

IND14, New generation of frequency standards for industry

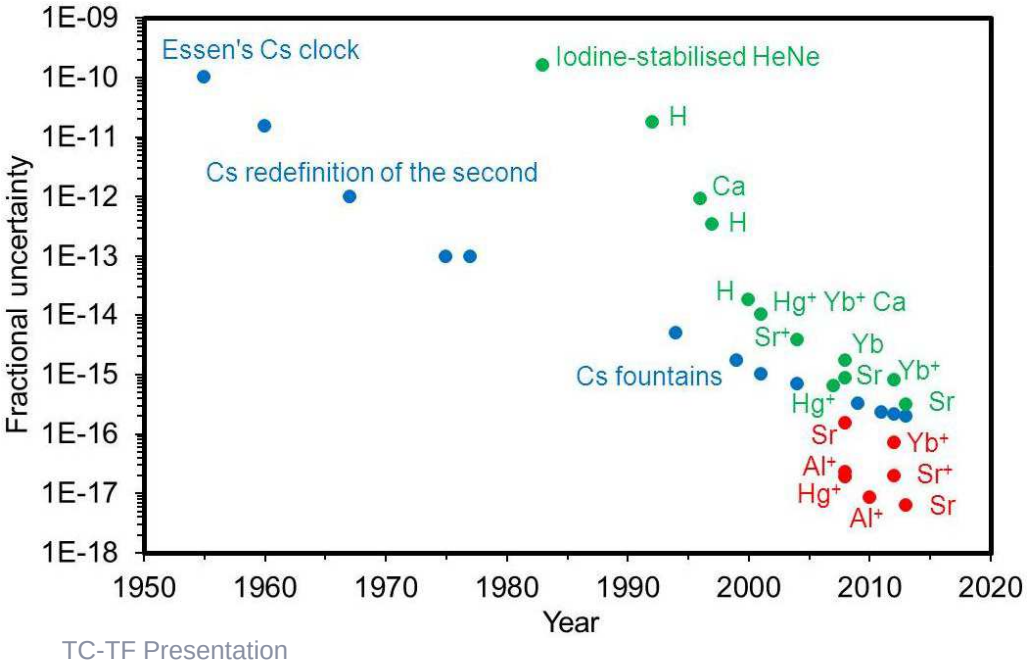
IND55, Compact microwave clocks for industrial applications

SIB02, Accurate time/frequency comparison and dissemination through optical telecommunication networks

SIB60, Metrology for long distance surveying

EXL01, Quantum engineered states for optical clocks and atomic sensors

Evaluation of atomic clocks and future optical redefinition of the second

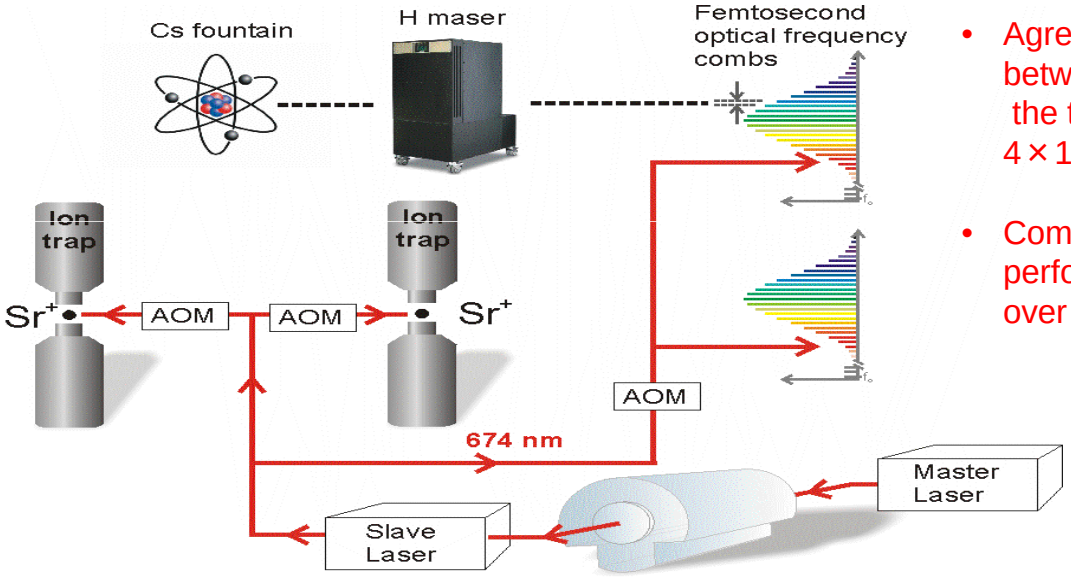


Microwave and Optical Clocks

TC-TF 2015

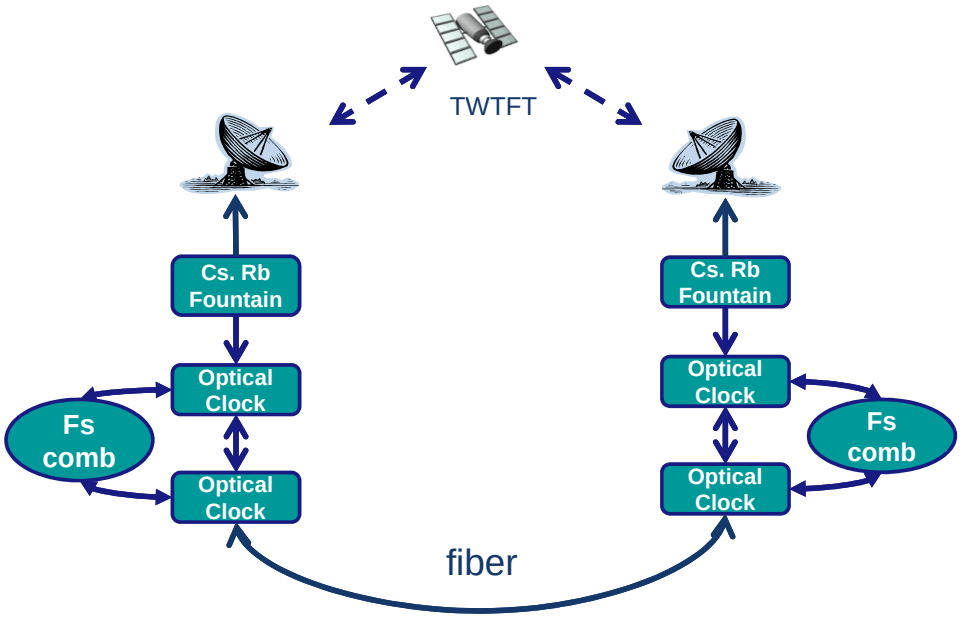
SIB04, High-accuracy optical clocks with trapped ions

Aim: development of ultra - precise optical clocks using laser - cooled trapped ions.



- Agreement between the two traps at 4×10^{-17}
- Comparisons performed over 9 months

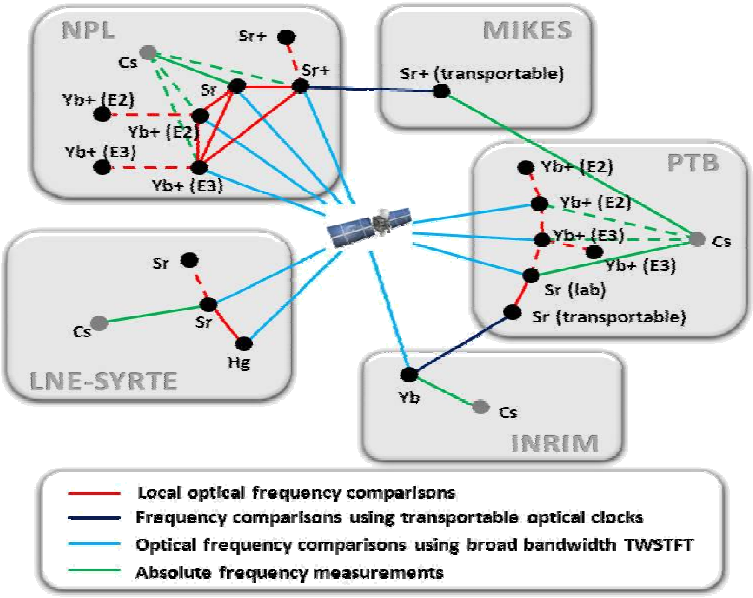
Time and Frequency Dissemination and Comparison



Satellite <1ns

Fiber: 1ms – 0.1ns
10^{-17} - 10^{-16}

SIB55, International timescales with optical clocks



Key Deliverable:

Comparison at 10^{-17} - 10^{-16} level,

Future optical redefinition of the second

NEXT: SRT-s16, Optical Clocks with 10^{-18} uncertainty

Time and Frequency Dissemination Using Fibers

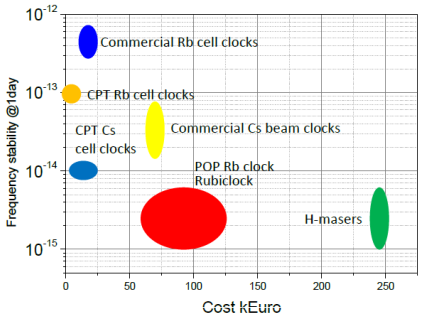
Developments techniques for frequency comparisons at ~10^{-18} at 1 day (0.1 ps/day)

NEXT:~10^{-19} at 1 day
SRT-s15, Optical Frequency Transfer – a European Network

T&F dissemination trough fiber in EU – Blood vessel in human body

Time and Frequency Applications

Developments of compact and low cost atomic clocks for industry

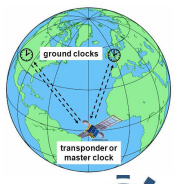


Development Low Phase Noise RF-MW Oscillator Based on Femtosecond Lasers

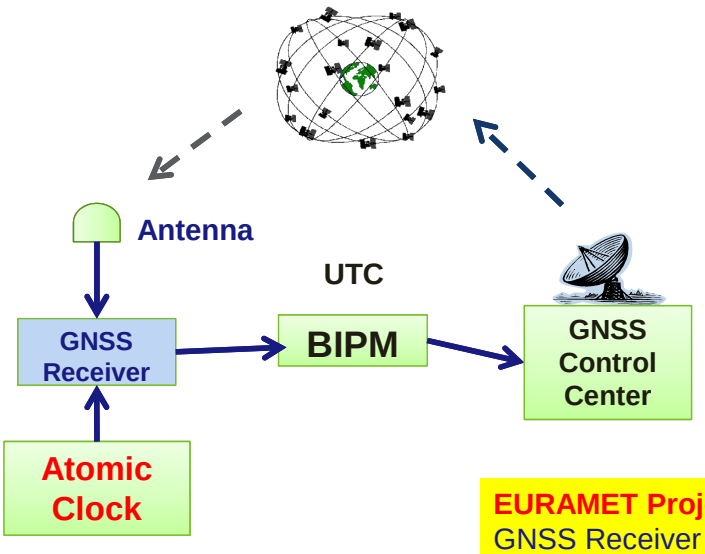
Clock Based Geodesy 10^{-18} ⟶ **1 cm**

Direct measurement of the Earth's gravity potential with high resolution using the gravitational redshift

$$Z \equiv \frac{\Delta f}{f} = \frac{\Delta U}{c^2}$$



Time scale generation with low uncertainty



Atomic Clocks Accuracy
10^{-14} - 10^{-16}

Time deviation
$\Delta t / t = \Delta f / f$ = 1 – 0.01 ns/day

Time scale generation depends
- Delay on antenna
- Delay on Cables
- Delay on GNSS receivers

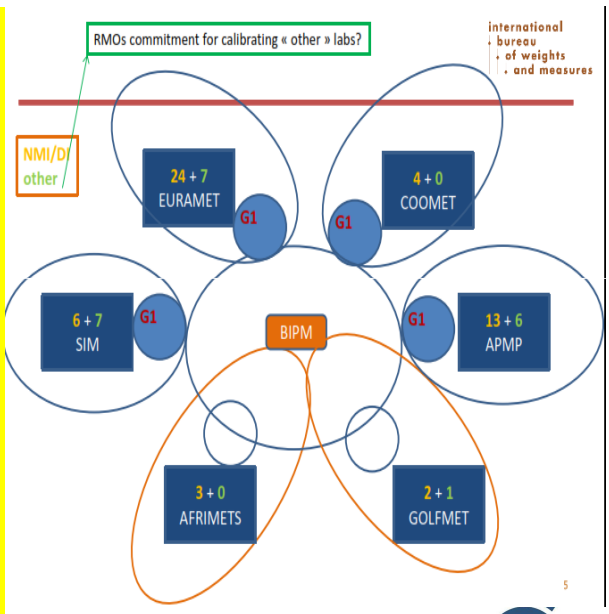
Time Scale Shift
UTC- UTC(k) : **5 -100 ns**

EURAMET Projects:
GNSS Receiver Comparisons
Cable Delay Measurements

GNSS Receiver Comparison

- **BIPM** prepared **Guidelines**
- Sharing with RMOs the task of GNSS equipment calibration for UTC time comparisons,
- Most TF labs contributing to UTC with **u_B uncertainty ≈7 ns**
- Contributing to the evaluation of the **u_B, targeting at 2-3 ns**

Pilot G1 Laboratories: ROA, PTB, LNE



Thank you for your attention

UME fs Comb Light for Metrology Day