

The State of the Art in Amateur Timekeeping

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Seattle, WA

Outline

- Amateurs & precise timekeeping
- Collecting atomic clocks
- Stability measurements
- Cesium experiment
- Maser experiment



Amateurs with atomic clocks

- Ham radio
- Timing industry employees
- Retired military personnel
- Computer engineers (network sync)
- Clock and watch collectors
- *TACGPS, time-nuts*

The collection...

- Austron, Astrodata, Berkeley (BNC), Bliley, Datum, Efratom, FEI, Fluke, FTS, GenRad, HP/Agilent, Kinematics, Odetics, Oscilloquartz, Stanford (SRS), Spectracom, Sulzer, Symmetricom, Tracor, Trak, TrueTime, Vectron

HP quartz

- 105B
- 107BR
- 106B
- 104AR
- 103AR
- 101A
- 100ER



HP cesium & rubidium

- 5071A
- 5065A
- 5062c
- 5061B
- 5061A
- 5060A



HP clocks

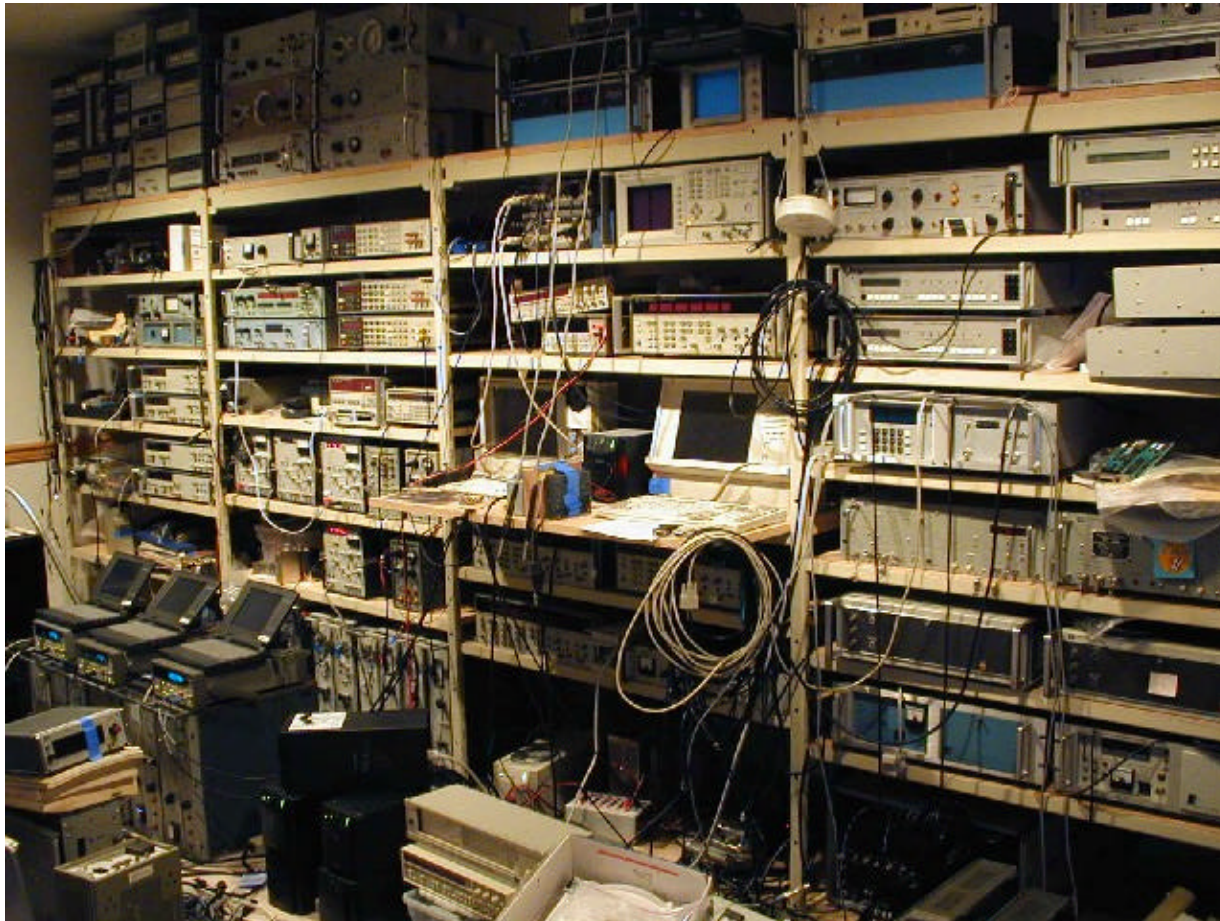
- HP01
- 571B
- 5321
- 117A
- 114BR
- 115BR
- 113AR



Where do these come from?

- Ham radio conventions
- Surplus stores (local)
- Used test equipment dealers (net)
- Usenet
- Gifts
- eBay

More gear (upper lab)



Time scale (lower lab)



Some measurements

- Sulzer quartz
- HP quartz
- HP cesium
- FTS cesium
- Two 5071A's
- Two masers

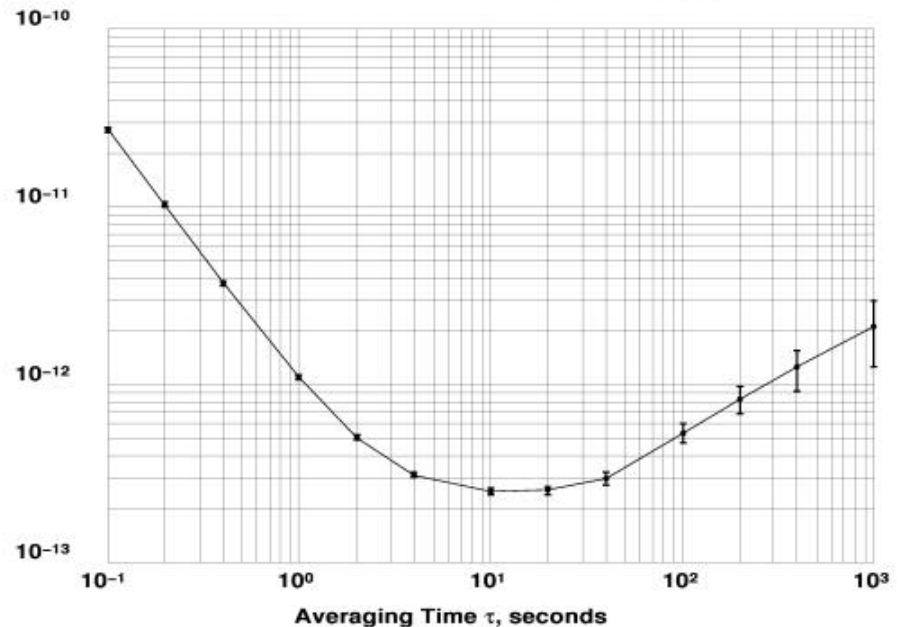
Sulzer 2.5C quartz

- $< 3e-13 \tau$ 10s



23 Jul 2001 00:18:48

Allan Deviation $\sigma_y(\tau)$



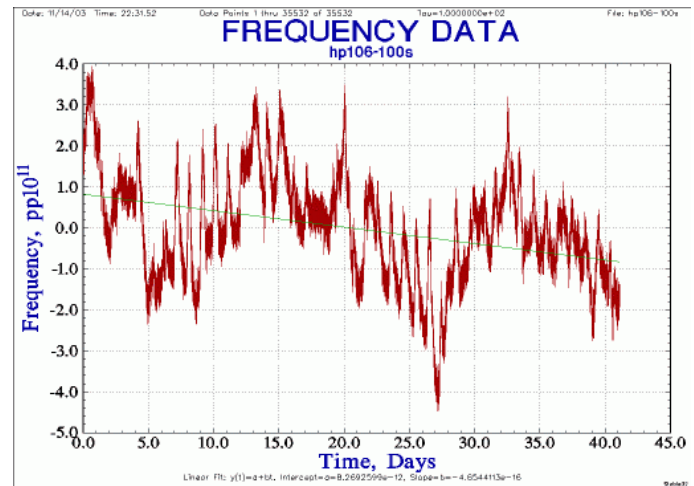
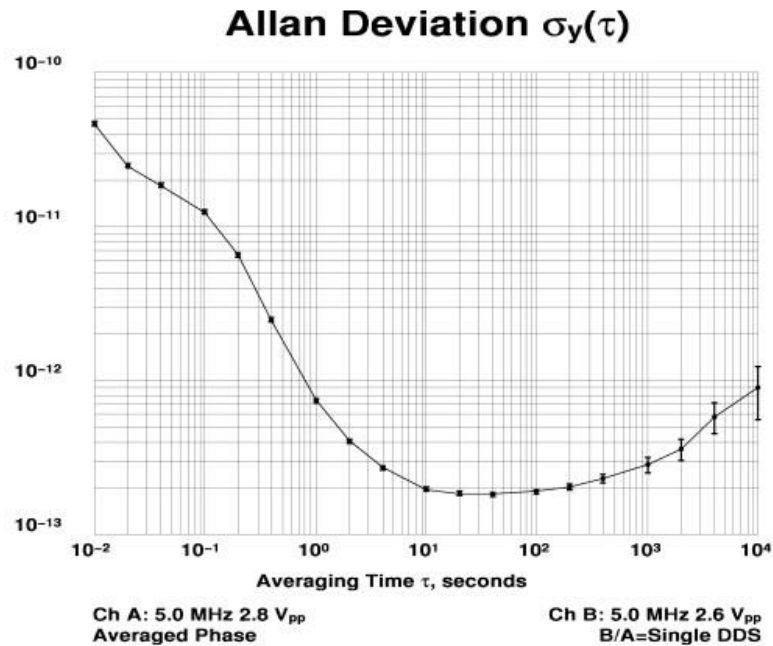
Ch A: 5.0 MHz 2.8 V_{pp}
Averaged Phase

Ch B: 2.5 MHz 2.8 V_{pp}
B/A=0.49999999739485

HP 106B quartz

- $4e-13/\text{day}$ drift

24 Jul 2001 15:55:28

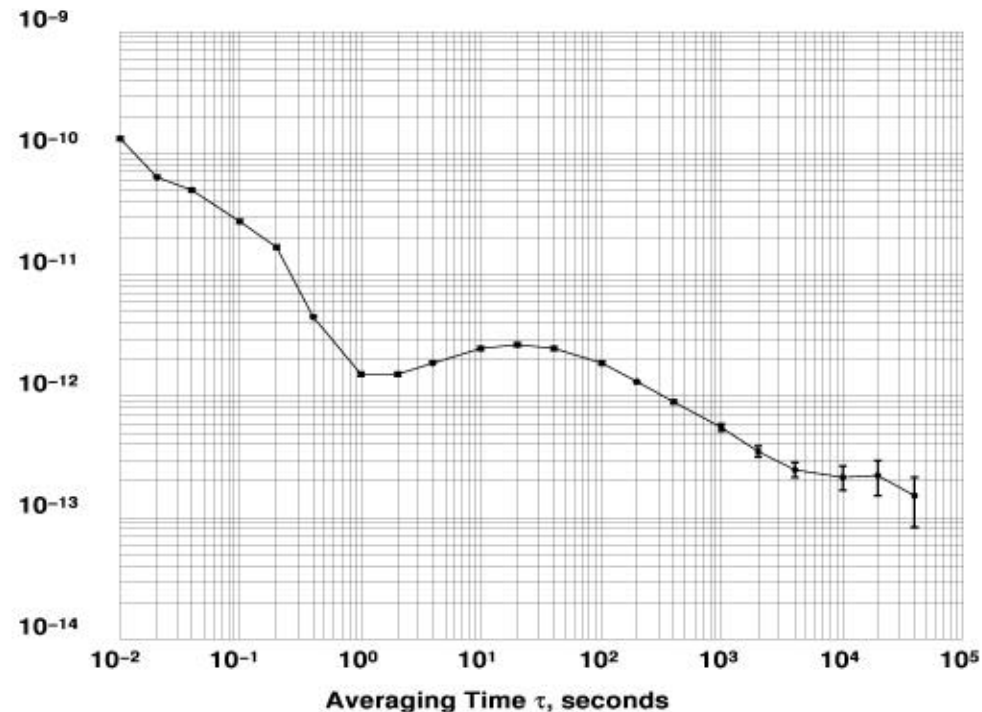


HP 5060 cesium

- $< 2e-13$
- τ 40k

22 Oct 2003 20:46:12

Allan Deviation $\sigma_y(\tau)$



Ch A: 5.0 MHz 2.7 V_{pp}
Averaged Phase

Ch B: 5.0 MHz 2.8 V_{pp}
B/A=Single DDS

C:\tvb\Tscpl0t\Log4141.gif

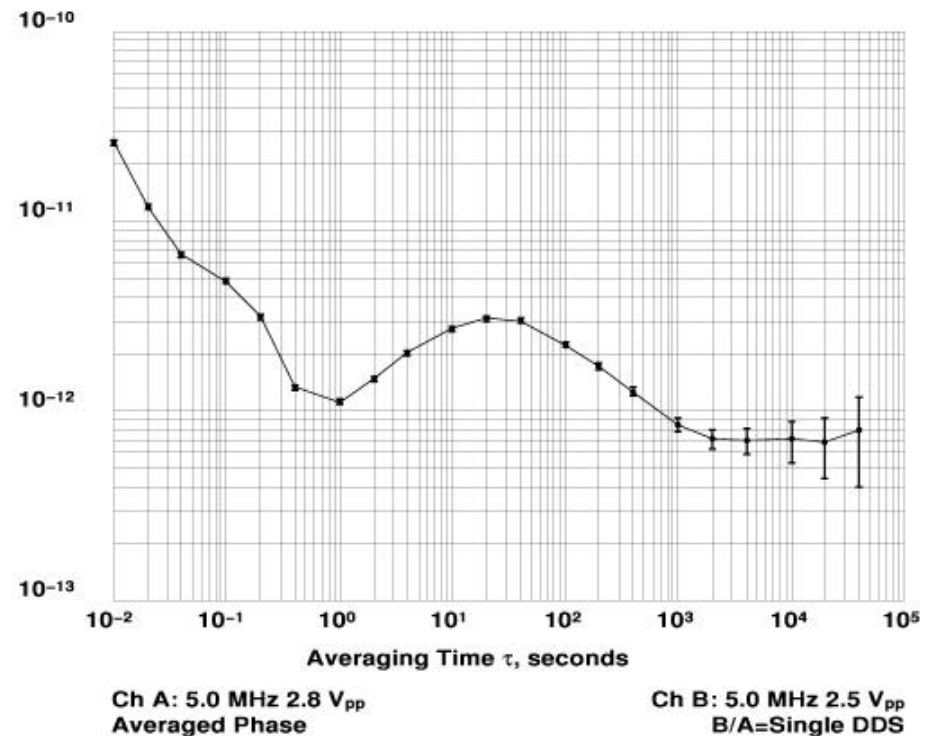
FTS 4010 cesium

- $>7e-13$
- Portable



20 Oct 2001 15:22:22

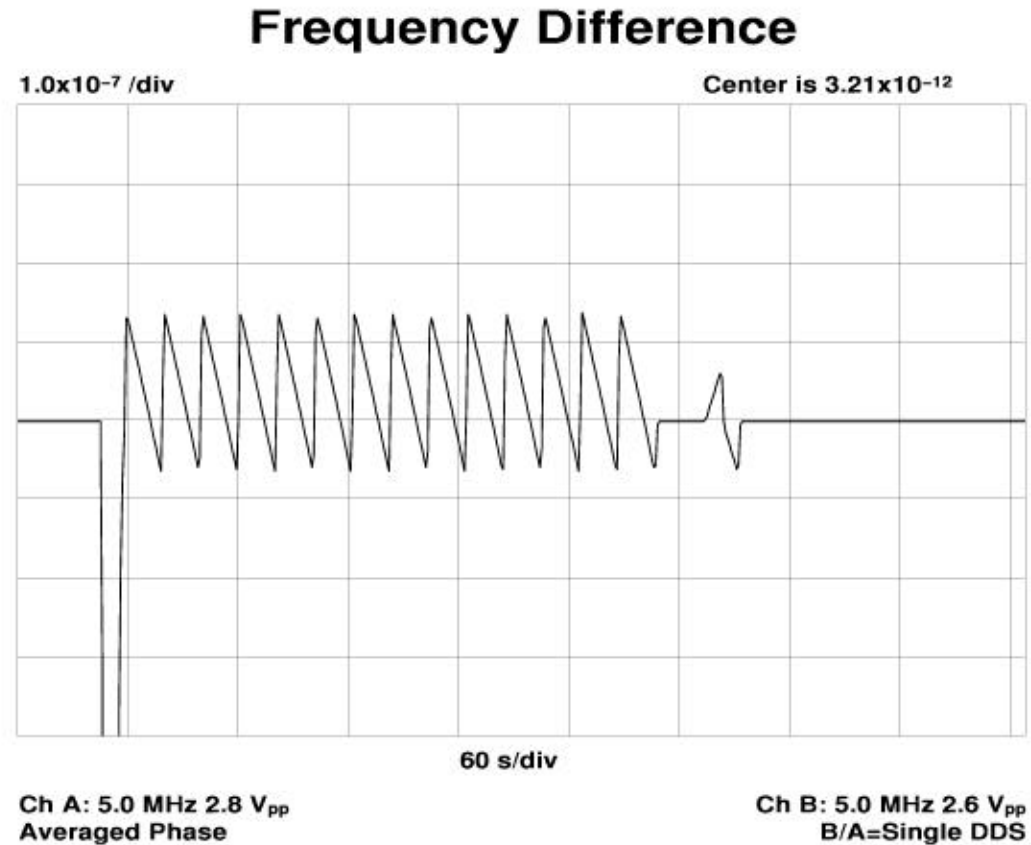
Allan Deviation $\sigma_y(\tau)$



FTS 4060 cesium

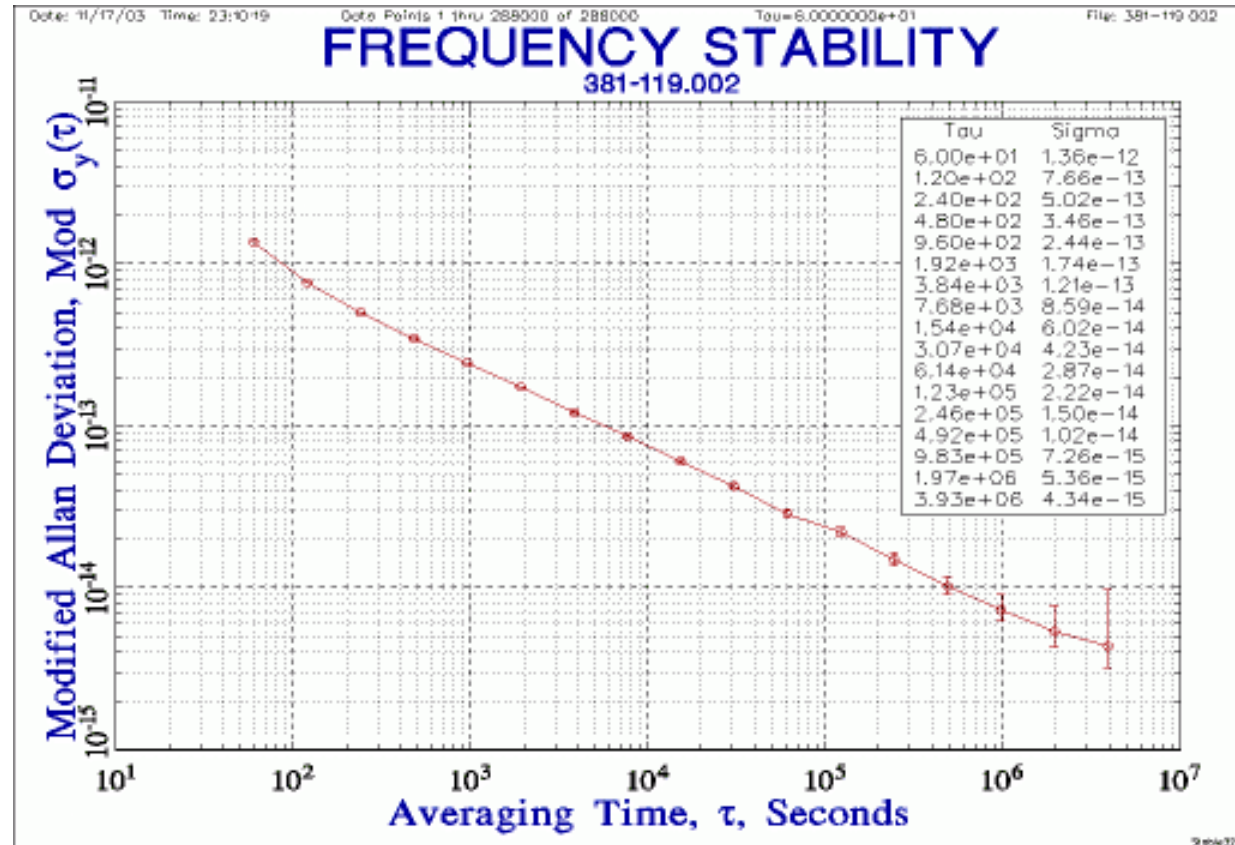
18 Oct 2001 08:43:43

- Locked
- Search
- Lock
- Check
- Locked



A pair of 5071A/001

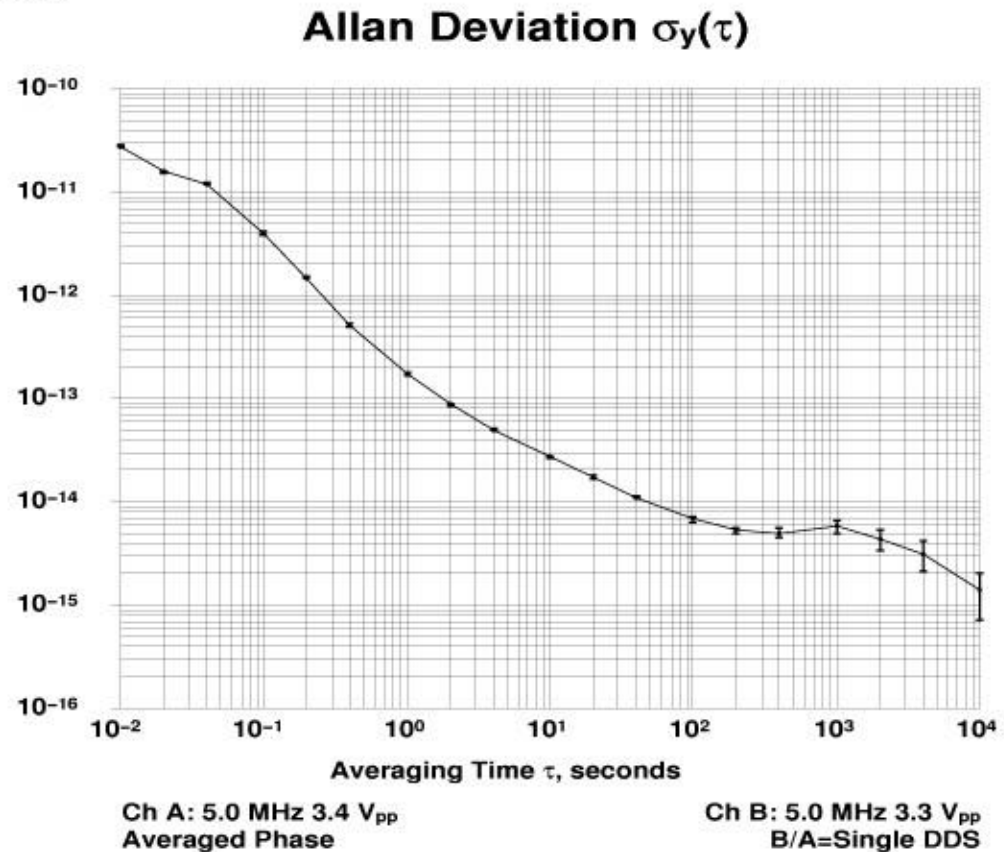
- $< 5e-15$
- τ 4M



A pair of H-Masers

- $< 2e-15$
- τ 10k

24 Nov 2003 09:23:21



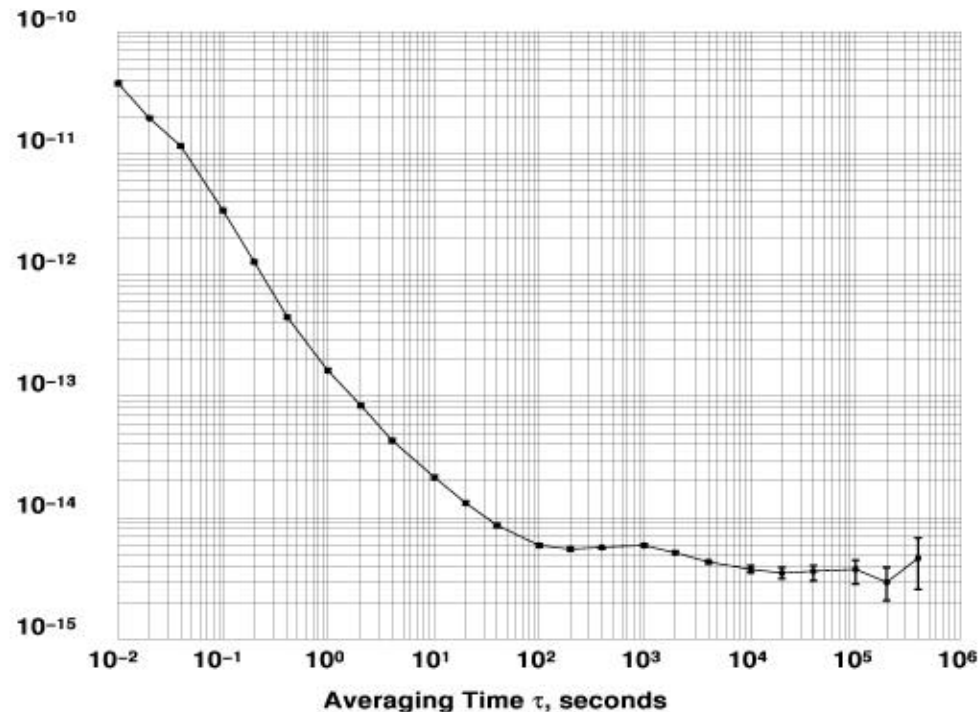
C:\tvb\TSCPlot\Log21376.gif

A pair of H-Masers

- $< 5e-15$
- τ 400k

23 Apr 2003 22:04:27

Allan Deviation $\sigma_y(\tau)$

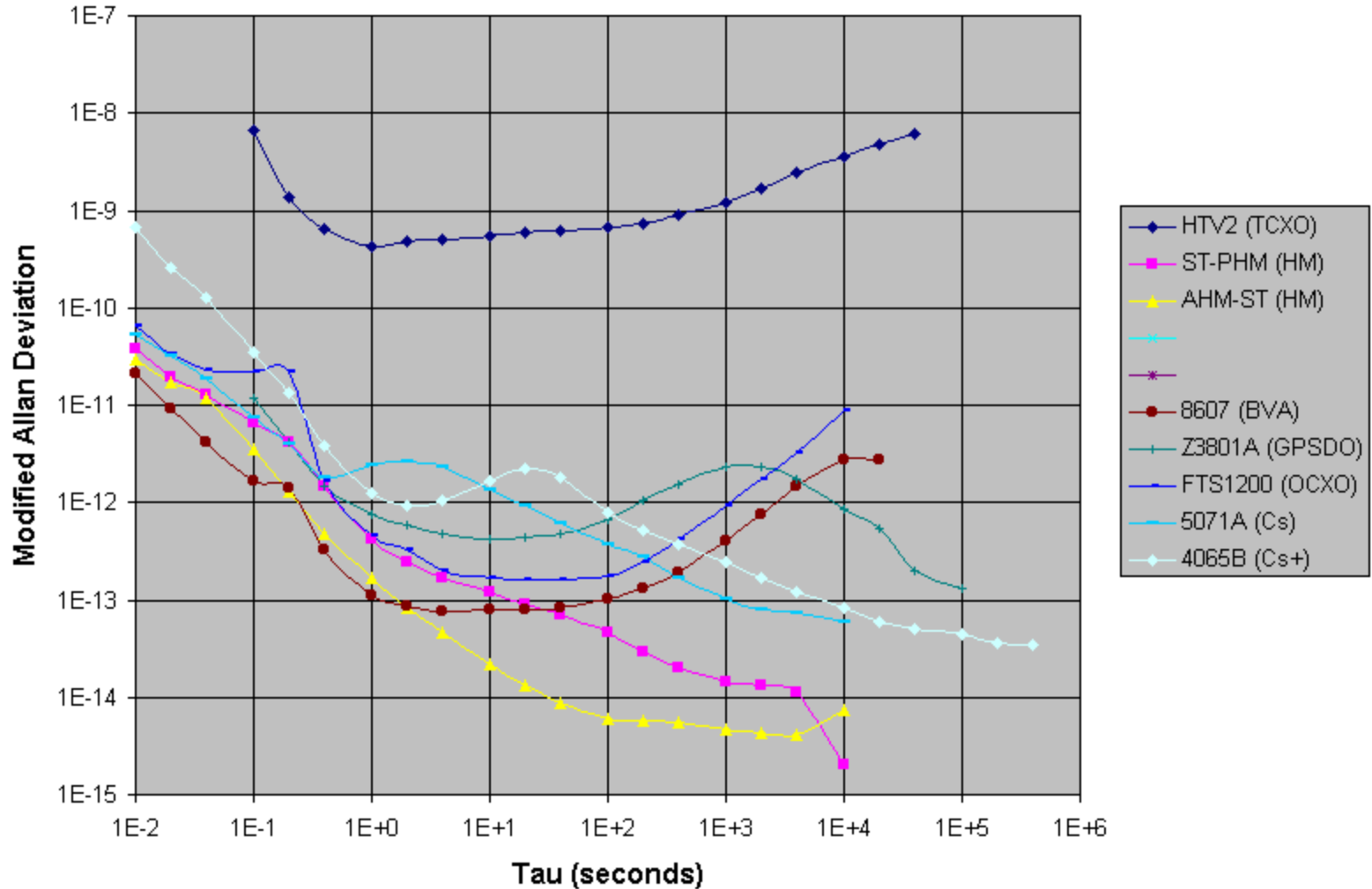


Ch A: 5.0 MHz 2.5 V_{pp}
Averaged Phase

Ch B: 5.0 MHz 3.4 V_{pp}
B/A=Single DDS

C:\tvb\Tscpl0t\Log20180.gif

Oscillator Stability Comparison

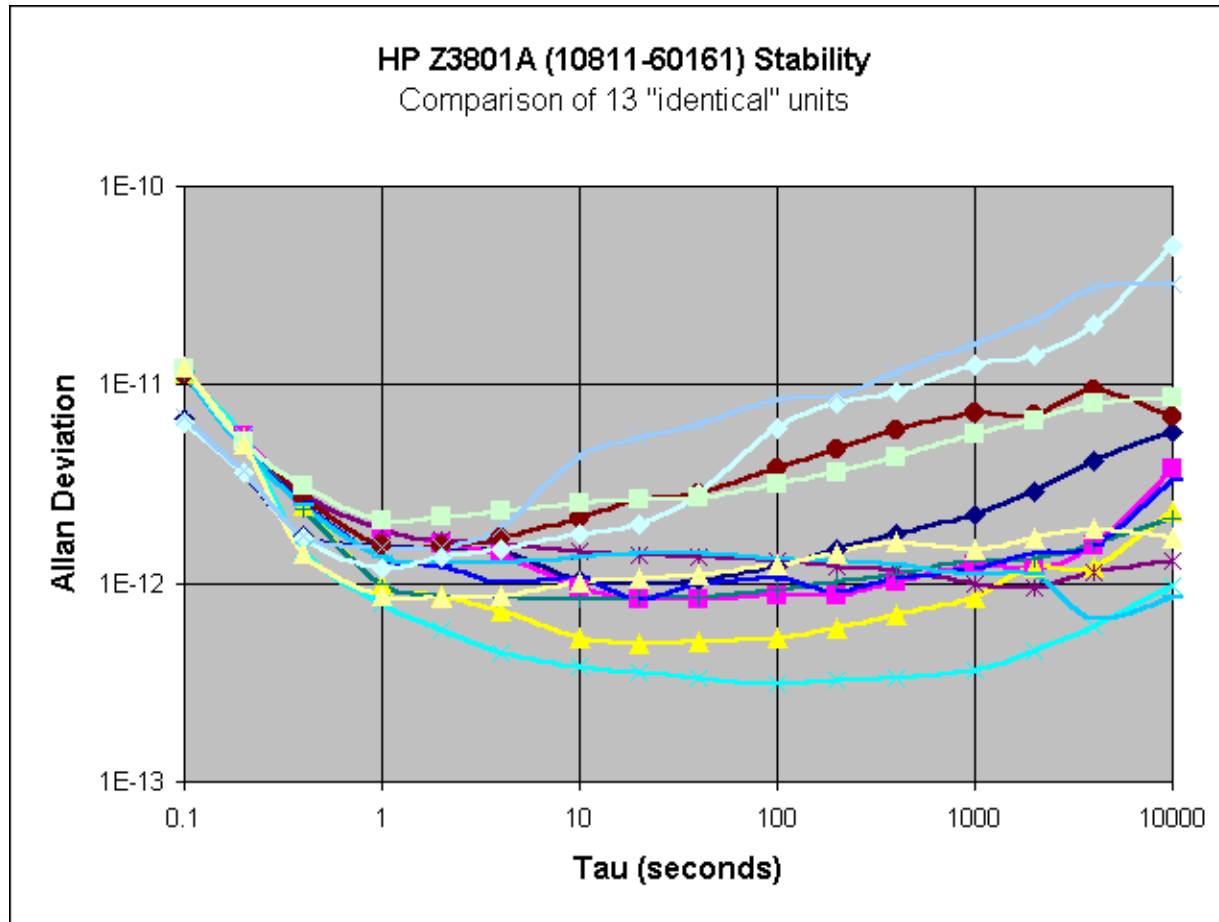


All measurements by tvb@LeapSecond.com

Some experiments

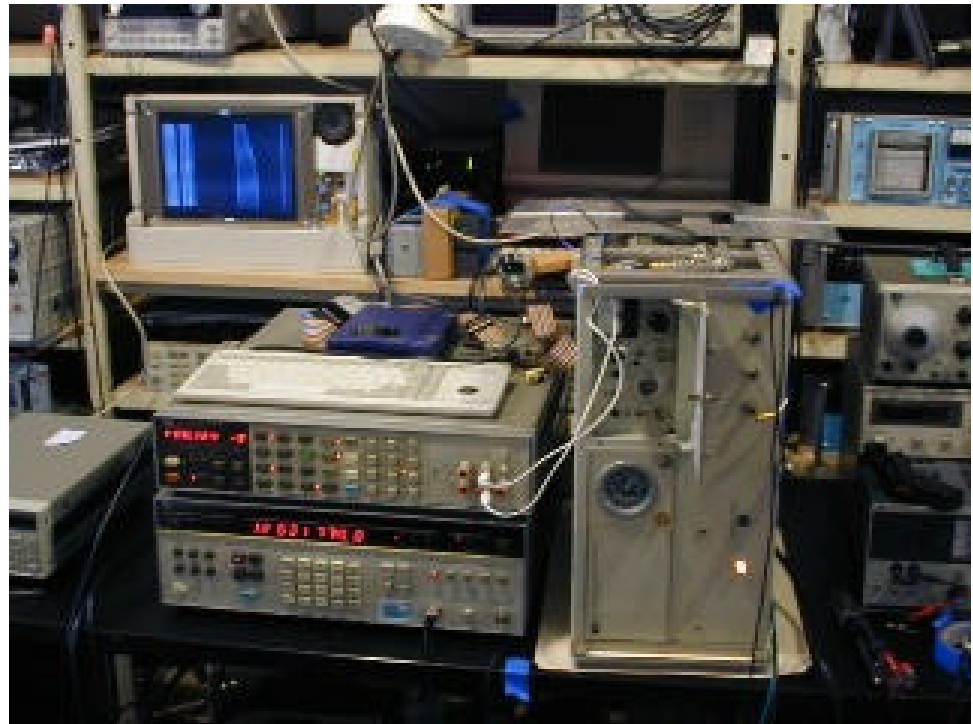
- HP 10811 OCXO variations
- Cesium resonance
- Maser cavity auto-tuning

Z3801A OCXO variations

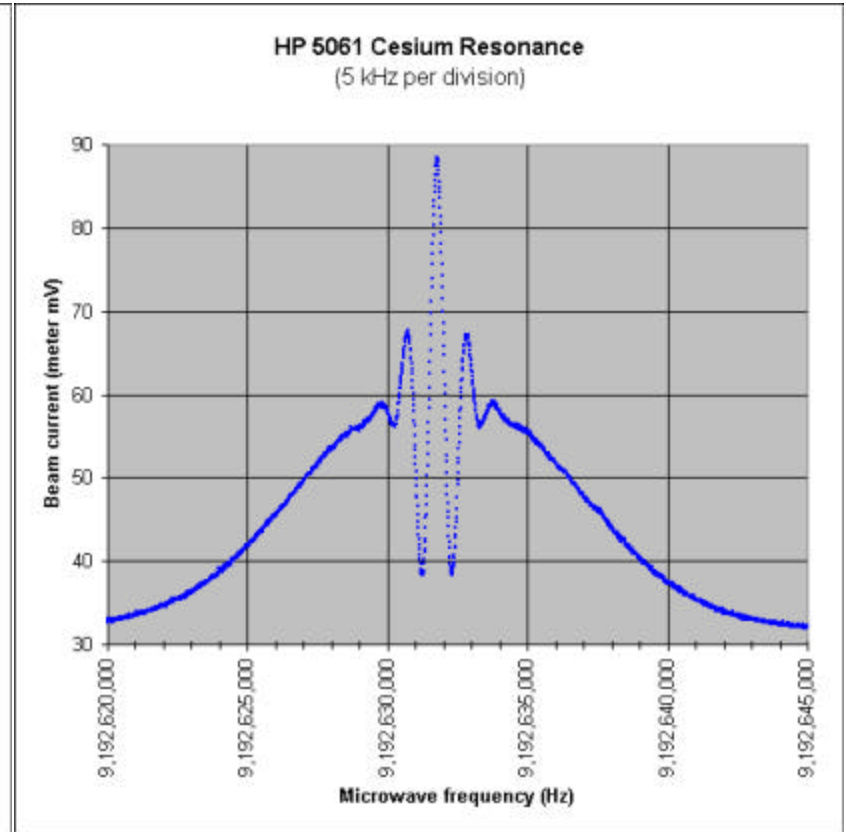
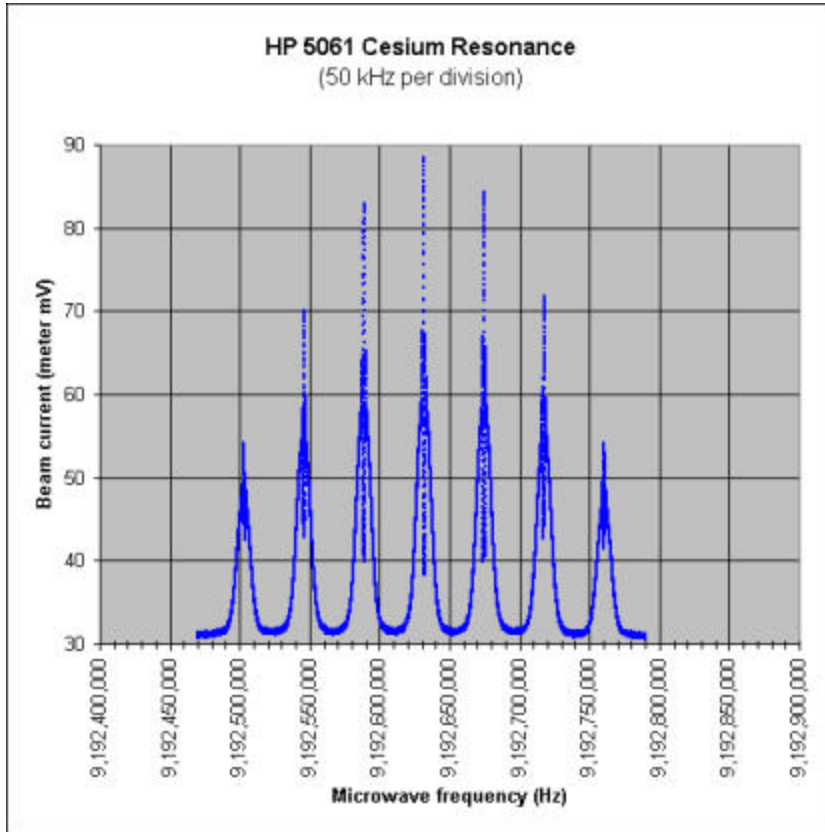


Fun at 9,192,631,770 Hz

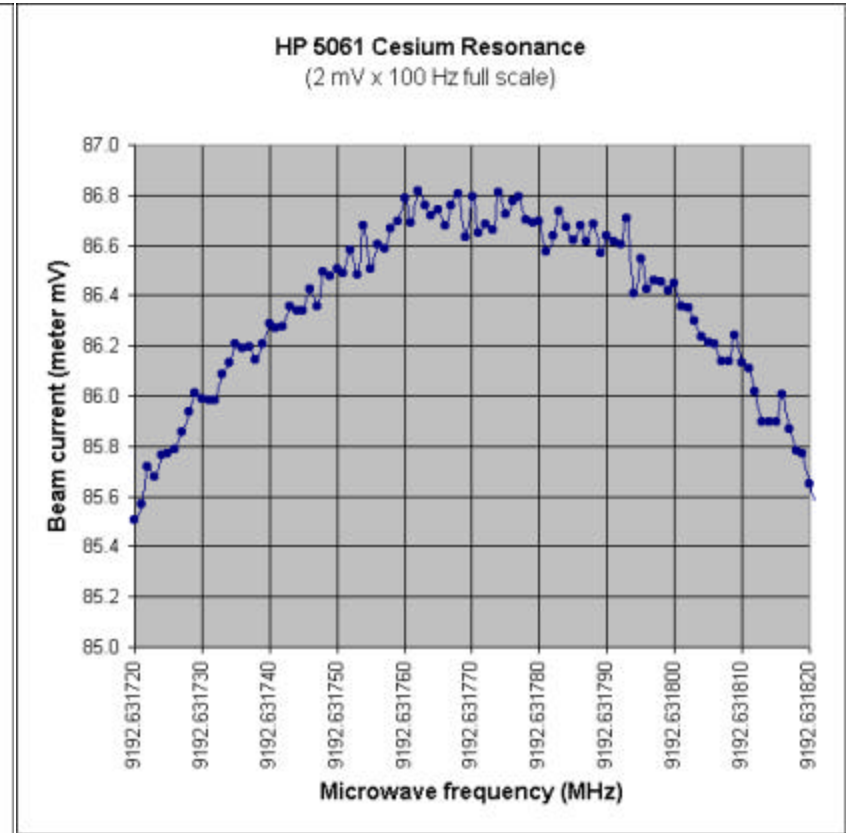
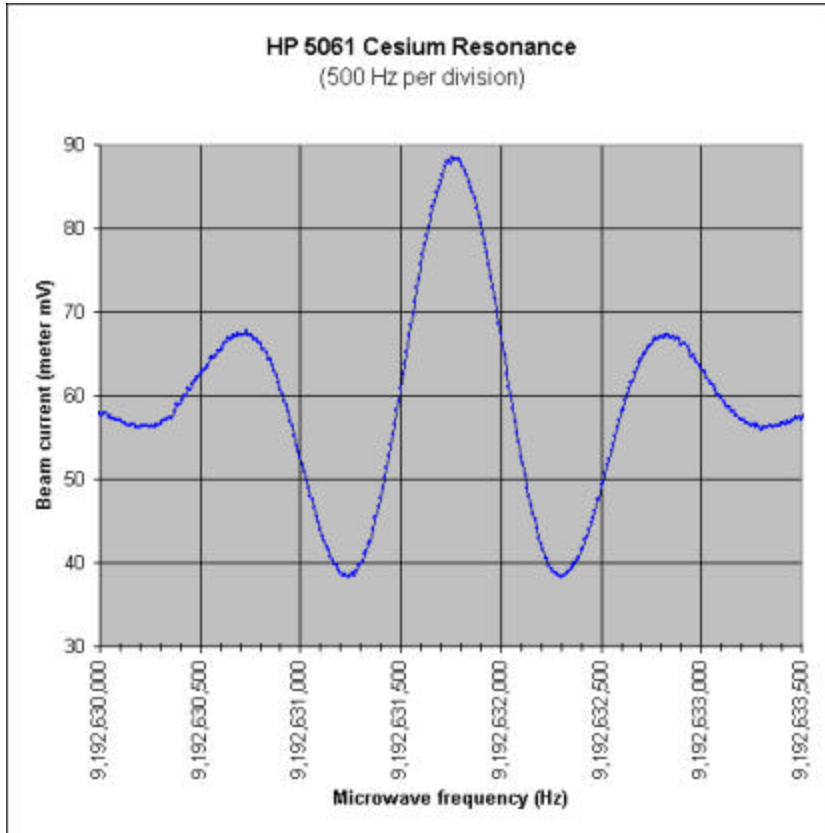
- 9180 MHz
- +12.6 MHz
- Synthesizer:
HP 3325A
- Voltmeter:
HP 3456A



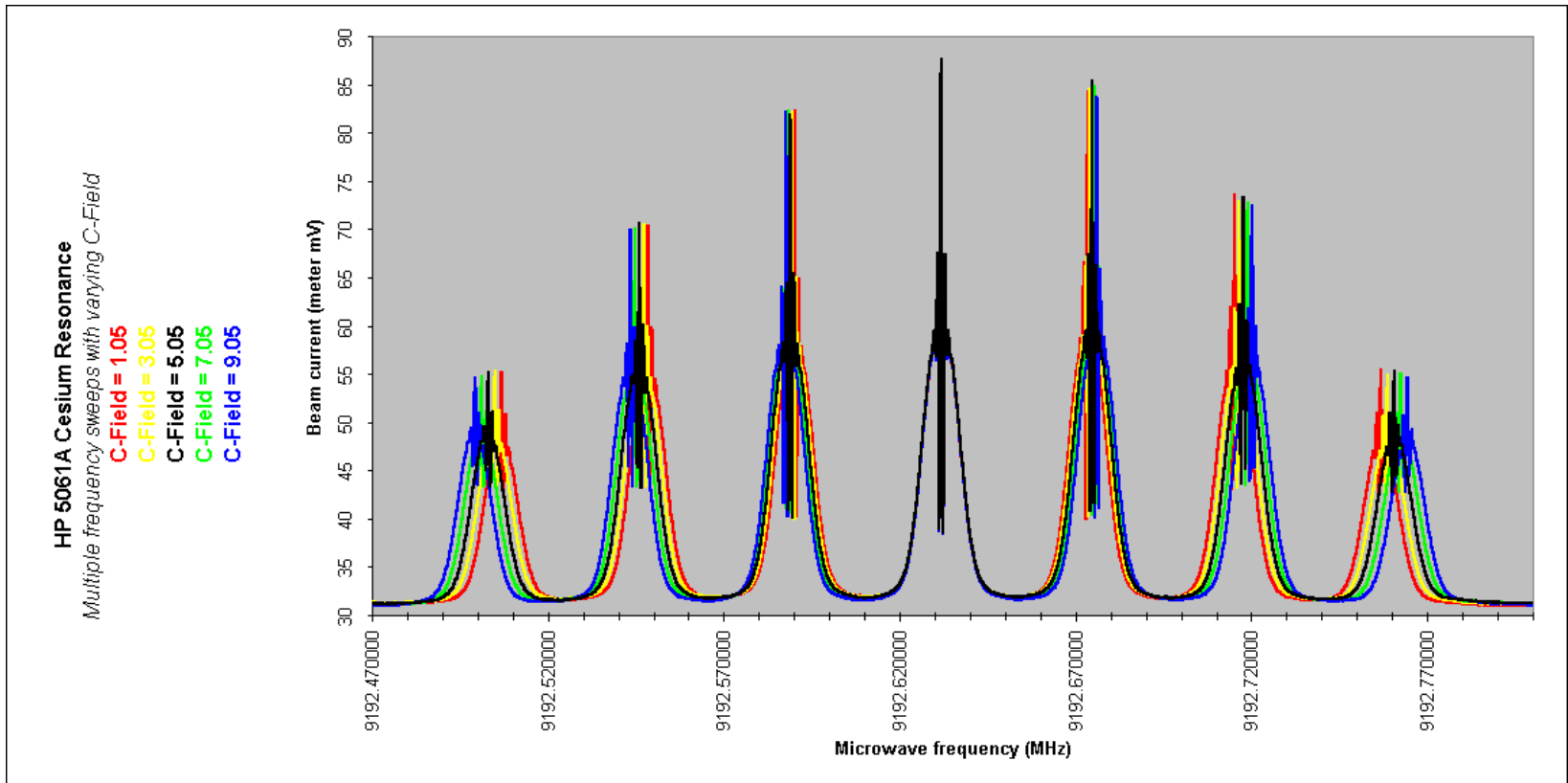
Cesium resonances



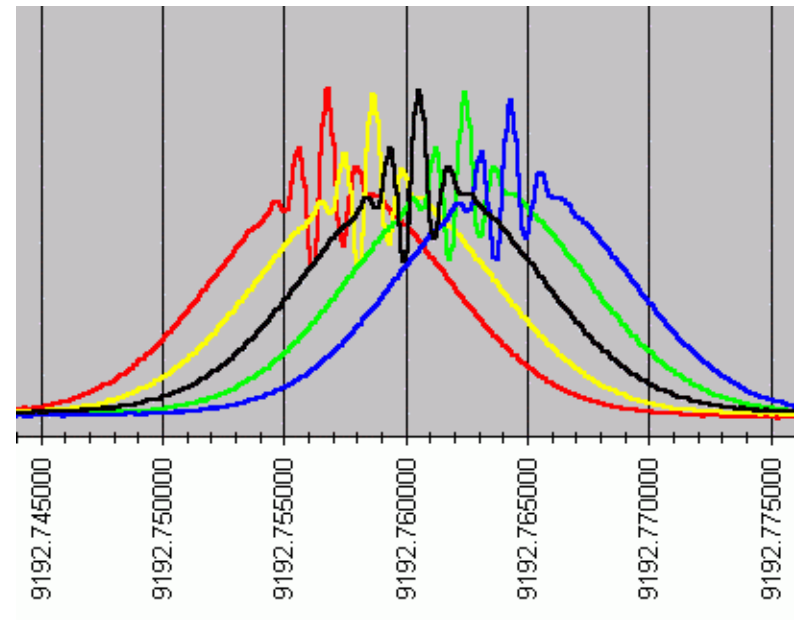
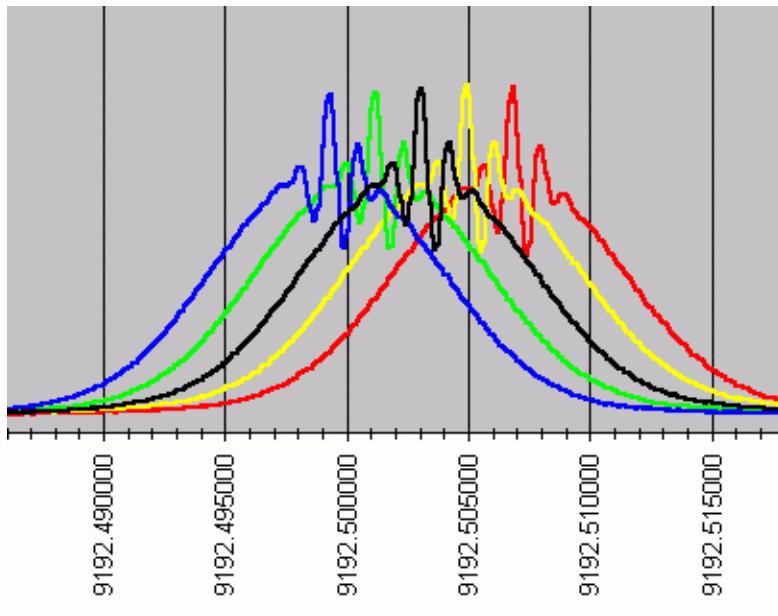
Cesium resonance



C-field spreading of 7 peaks

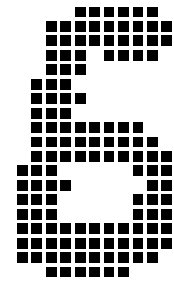
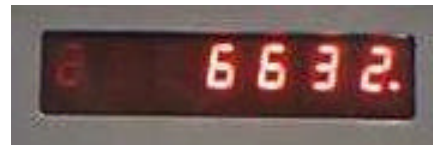


1st and 7th peak detail



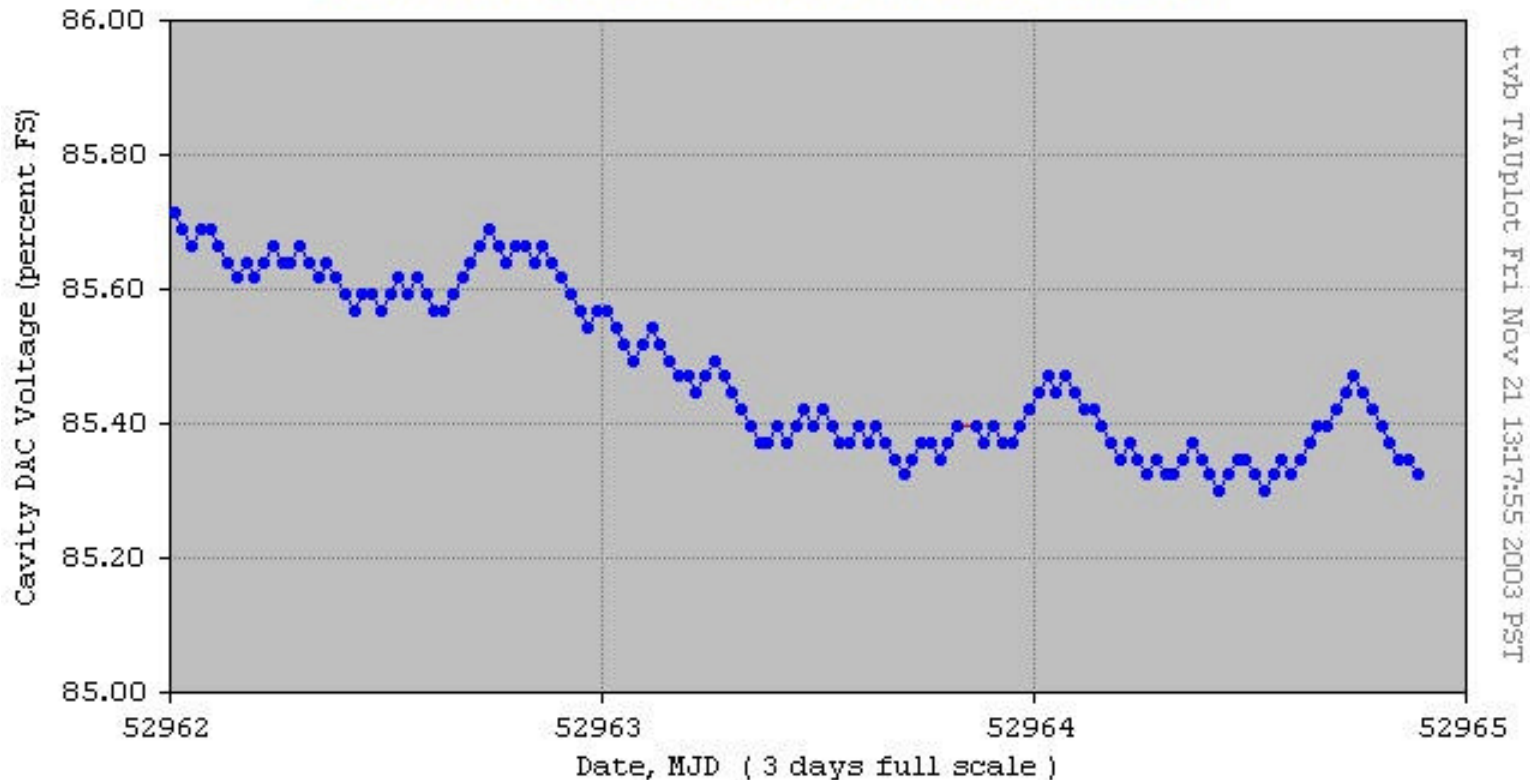
Maser cavity DAC webcam

- Missing RS-232
- Octal LED
- Webcam (jpg)
- OCR digit (bmp)
- TAUplot
- FTP to website



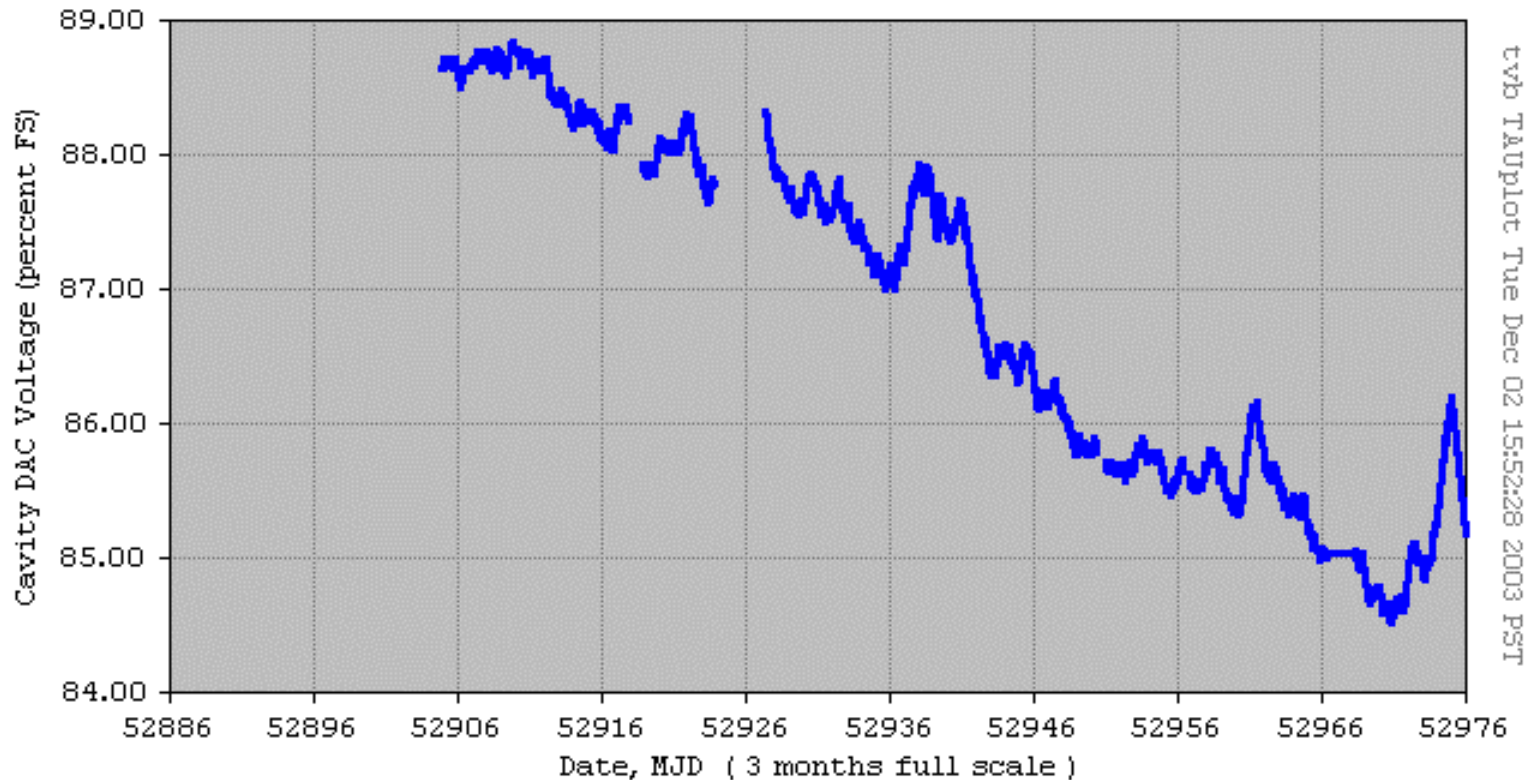
Maser cavity DAC – 3 days

CH1-75 Active H-Maser Cavity Tuning



Maser cavity DAC – 3 months

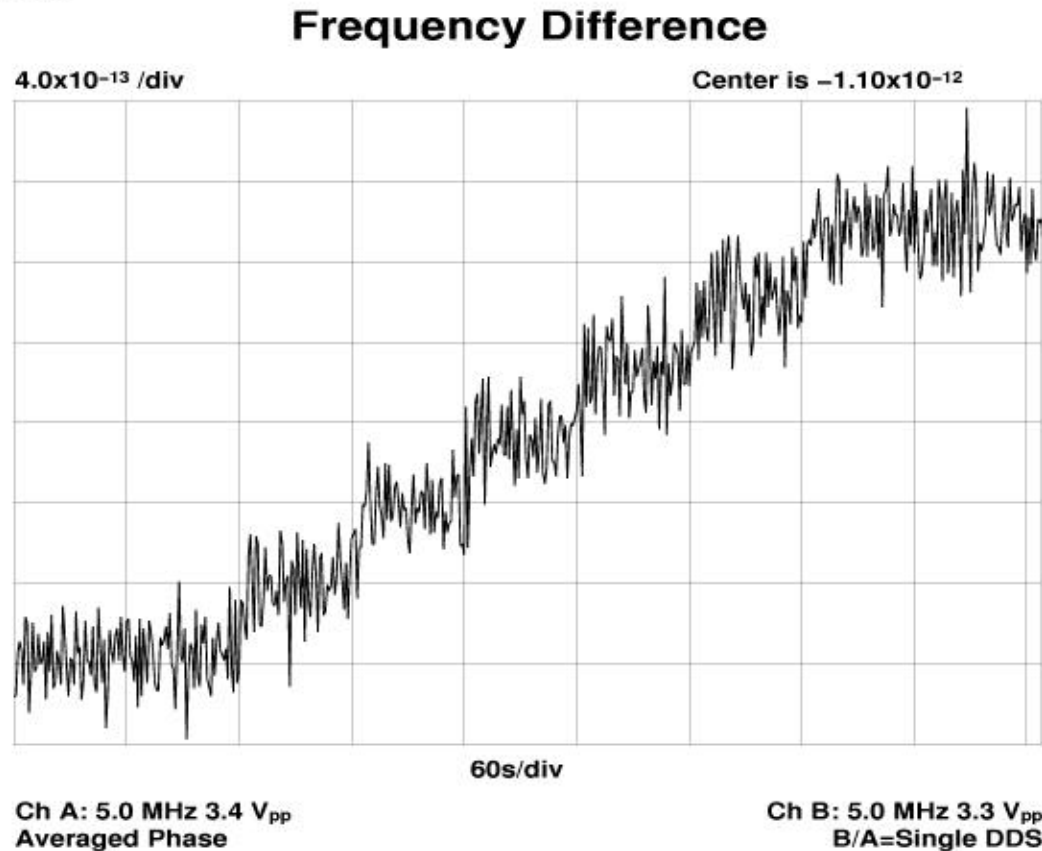
CH1-75 Active H-Maser Cavity Tuning



Maser DAC calibration

- Octal DAC
- from 1000
- to 7000
- step 1000
- every 60 s
- $2.7e-12$ FS
- $6.8e-16$ /bit

14 Nov 2003 12:04:40



C:\tvb\Tscplot\Log21274.gif

Summary

- Collecting hobby
- Measurements & experiments
- Virtual time/frequency museum
(donations welcome!)
- Most accurate [home] clock
- My website:

www.LeapSecond.com

29 Nov 2003 62:28:15?

- Oncore VP GPS Receiver

```
@@Ba 0b1b07d3173b39000d8ac... 11/27/2003 23/59/57.000887502
@@Ba 0b1b07d3173b3a000dbf3... 11/27/2003 23/59/58.000900912
@@Ba 0b1b07d3173b3b000df39... 11/27/2003 23/59/59.000914325
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Bill's Cesium wristwatch ;-)

