Frequency (and Time) Standards

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Why do you need a frequency Standard?

- Need to know what frequency you are on.
- Licence conditions
- Use of narrower bandwidths
- Also increasingly accurate timing is required for many of the newer digital modes.

History of Frequency Accuracy

- Early pioneers used spark and the bandwidth was large frequency accuracy was 1 – 10%
- Presently digital modes at microwave frequencies require accuracies of the order of 1 in $10^9 - 10^{10}$

History of Timekeeping

TABLE 17.4 The Evolution of Time and Frequency Standards

Standard	Resonator	Date of Origin	Timing Uncertainty (24 h)	Frequency Uncertainty (24 h)
Sundial	Apparent motion of the sun	3500 B.C.	NA	NA
Verge escapement	Verge and foliet mechanism	14th century	15 min	1×10^{-2}
Pendulum	Pendulum	1656	10 s	1×10^{-4}
Harrison chronometer (H4)	Spring and balance wheel	1759	350 ms	4×10^{-6}
Shortt pendulum	Two pendulums, slave and master	1921	10 ms	1×10^{-7}
Quartz crystal	Quartz crystal	1927	10 μs	1×10^{-10}
Rubidium gas cell	^{87}Rb resonance (6,834,682,608 Hz)	1958	100 ns	1×10^{-12}
Cesium beam	^{133}Cs resonance (9,192,631,770 Hz)	1952	1 ns	1×10^{-14}
Hydrogen maser	Hydrogen resonance (1,420,405,752 Hz)	1960	1 ns	1×10^{-14}
Cesium fountain	^{133}Cs resonance (9,192,631,770 Hz)	1991	100 ps	1×10^{-15}

Measurement Uncertainties

TABLE 17.1 Uncertainties of Physical Realizations of the Base SI Units

SI Base Unit	Physical Quantity	Uncertainty
Candela	Luminous intensity	1×10^{-4}
Kelvin	Temperature	3×10^{-7}
Mole	Amount of substance	8×10^{-8}
Ampere	Electric current	4×10^{-8}
Kilogram	Mass	1×10^{-8}
Meter	Length	1×10^{-12}
Second	Time interval	1×10^{-15}

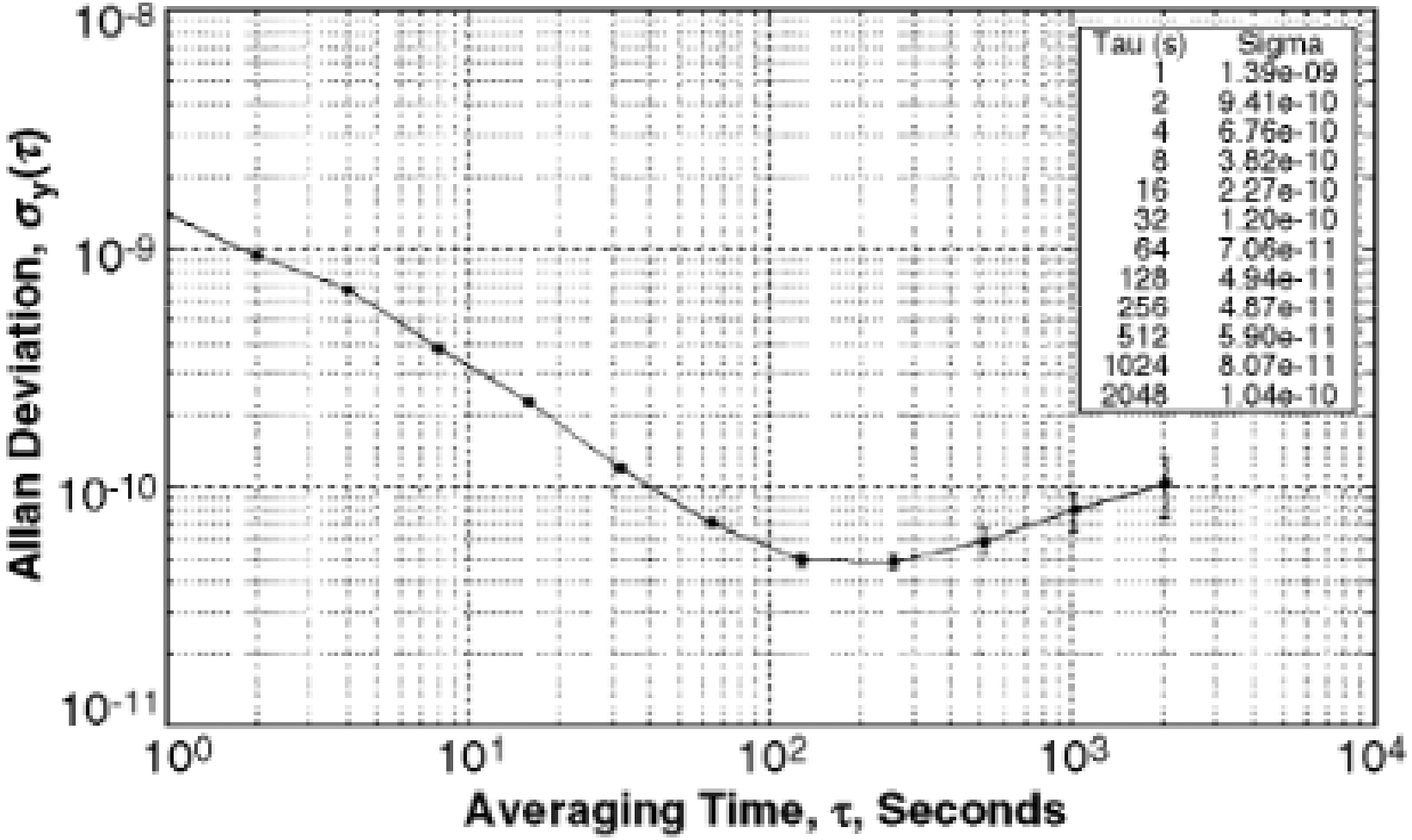
Measurement Uncertainties and Alan Deviation

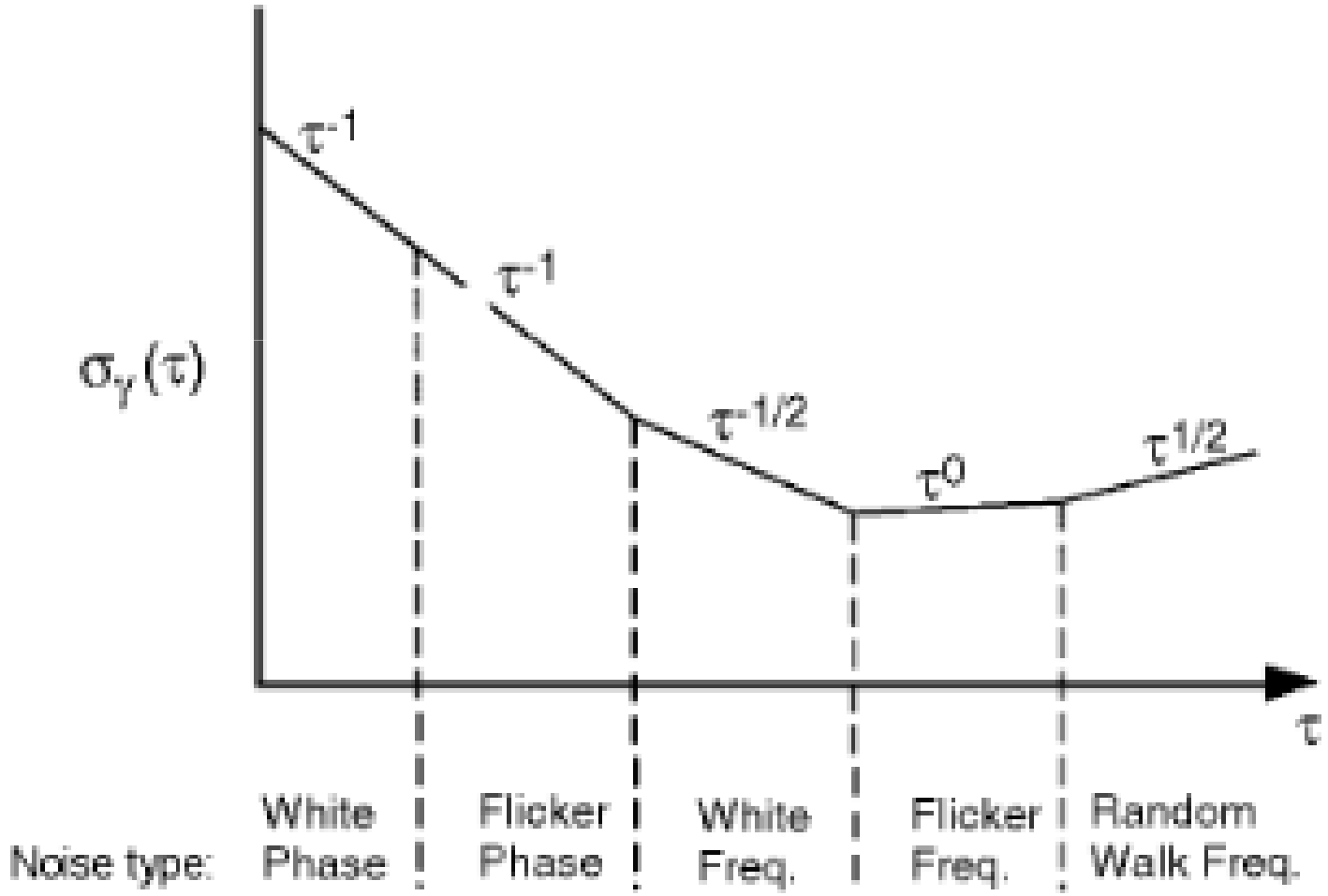
- All frequency sources have some degree of frequency variation. This can take the form of:

1. Phase noise
2. Amplitude noise
3. Slow drifts or instability

Measurement Uncertainties and Alan Deviation

- Short term fluctuations will show up with short sample times but average out over long sample times.
- Long term variations will only show over long sample times.
- A plot of this variability versus sample time is referred to as an Allan deviation plot. These are widely used to characterise oscillator stability.


Allan Deviation, $\sigma_y(\tau)$
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^0
10^1
10^2
10^3
10^4
Averaging Time, τ, Seconds
Tau (s) Sigma
1 1.39e-09
2 9.41e-10
4 6.76e-10
8 3.82e-10
16 2.27e-10
32 1.20e-10
64 7.06e-11
128 4.94e-11
256 4.87e-11
512 5.90e-11
1024 8.07e-11
2048 1.04e-10


$\sigma_y(\tau)$
τ^{-1}
τ^{-1}
$\tau^{-1/2}$
τ^{0}
$\tau^{1/2}$
τ
Noise type:
White Phase
Flicker Phase
White Freq.
Flicker Freq.
Random Walk Freq.

Allan Deviation $\sigma_y(\tau)$

Tau	Sigma(Tau)
2s	8.11E−11
4s	5.39E−11
8s	3.91E−11
10s	3.57E−11
20s	2.93E−11
40s	2.85E−11
80s	2.82E−11
100s	2.68E−11
200s	1.87E−11
400s	1.08E−11
800s	7.96E−12
1000s	8.05E−12
2000s	1.01E−11
4000s	1.74E−11
8000s	3.40E−11
10000s	4.24E−11
20000s	8.21E−11

Trace	Notes	Input Freq	Sample Interval	ADEV at 4s	Duration	Acquired	Instrument
Trimble		9.999999974 MHz	1.060 s	1.82E−10	4h 6m 2s	13926 pts	Hewlett Packard,5371A,0,2820
Symmetricom		9.999999970000001 MHz	1.060 s	5.39E−11	1d 0h 0m 0s	81509 pts	Hewlett Packard,5371A,0,2820

Hardware – What are the options?

Oscillator Type	Accuracy
Crystal Oscillator (XO)	$10^{-4} - 10^{-6}$
Temperature compensated XO (TCXO)	$10^{-7} - 10^{-8}$
Oven Controlled XO (OCXO)	$10^{-8} - 10^{-9}$
Double Ovened XO (DCOXO)	$10^{-9} - 10^{-10}$
Rubidium Locked (Rb)	$10^{-10} - 10^{-11}$
GPS Disciplined XO (GPSDO)	$10^{-10} - 10^{-12}$
Cesium Based Oscillators/Clocks	$10^{-12} - 10^{-15}$

Hardware – What Does it Cost?

Oscillator Type	Accuracy	$/£
Crystal Oscillator (XO)	$10^{-4} - 10^{-6}$	1 - 30
Temperature compensated XO (TCXO)	$10^{-7} - 10^{-8}$	10 - 20
Oven Controlled XO (OCXO)	$10^{-8} - 10^{-9}$	10 -30
Double Ovened XO (DCOXO)	$10^{-9} - 10^{-10}$	25 - 100
Rubidium Locked (Rb)	$10^{-10} - 10^{-11}$	70 - 150
GPS Disciplined XO (GPSDO)	$10^{-10} - 10^{-12}$	45 - 400
Caesium Based Oscillators/Clocks	$10^{-12} - 10^{-15}$	5K – 10K

TCXOs

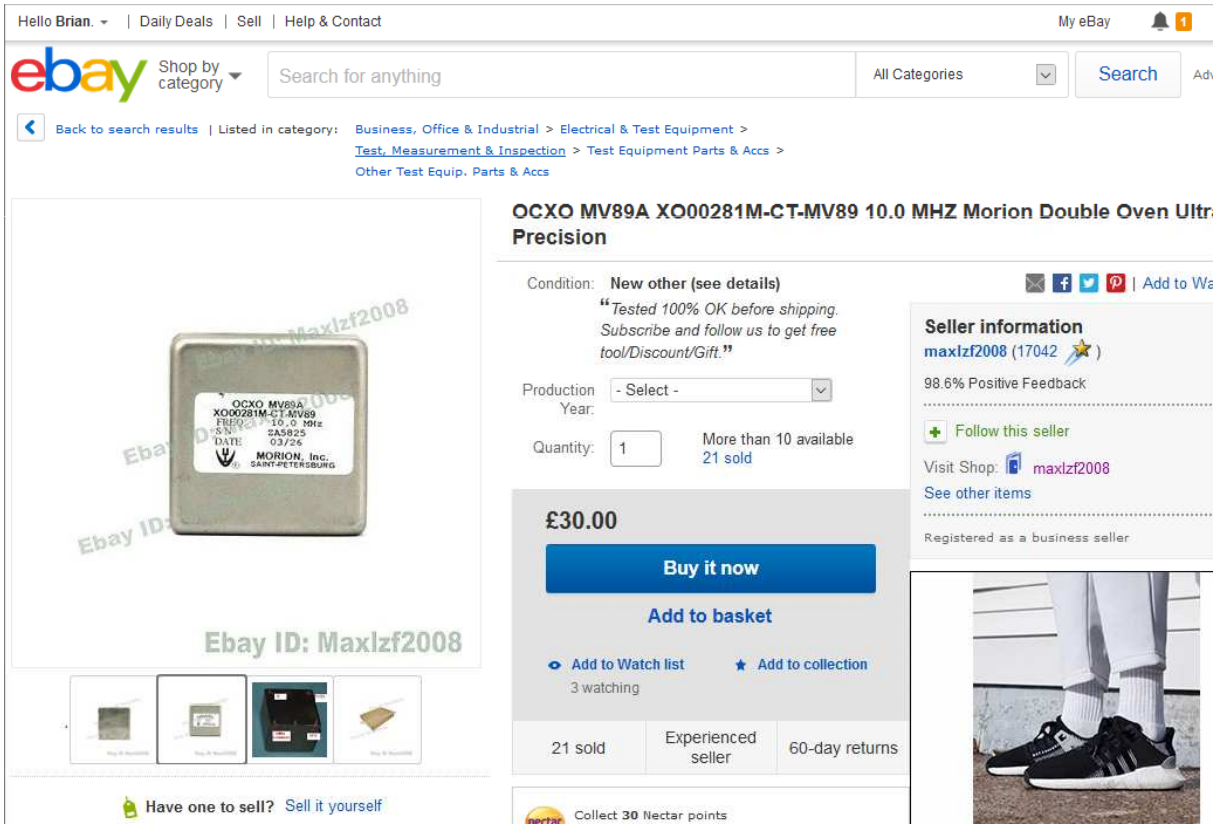
- Widely available on the surplus market.

10 MHz OCXOs

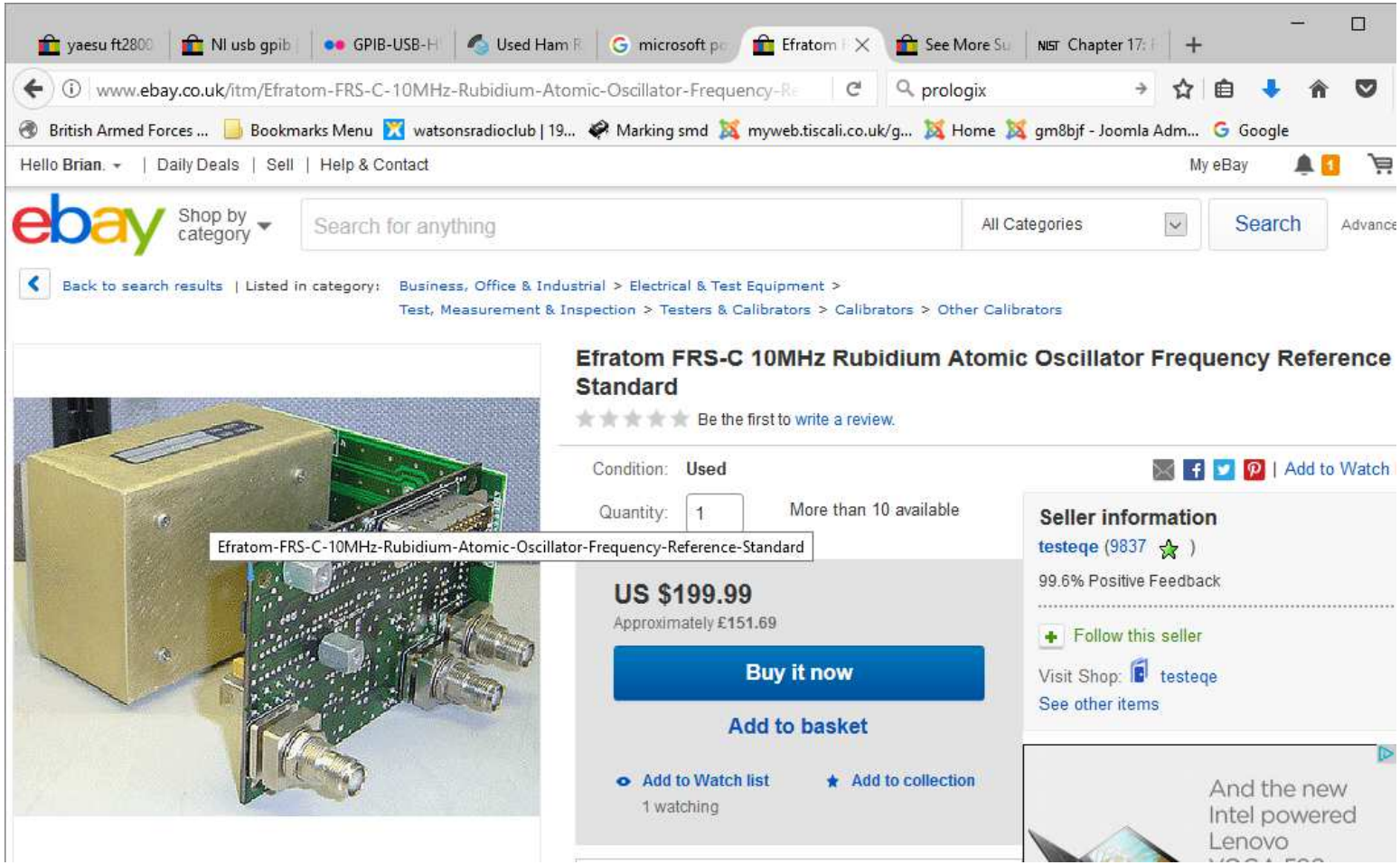
- Trimble
- Symmetricom
- Rakon
- Isotemp
- HP 10811
- Buckets of them on Ebay from China

10 MHz DOCXOs

- Morion MV89A – excellent performer



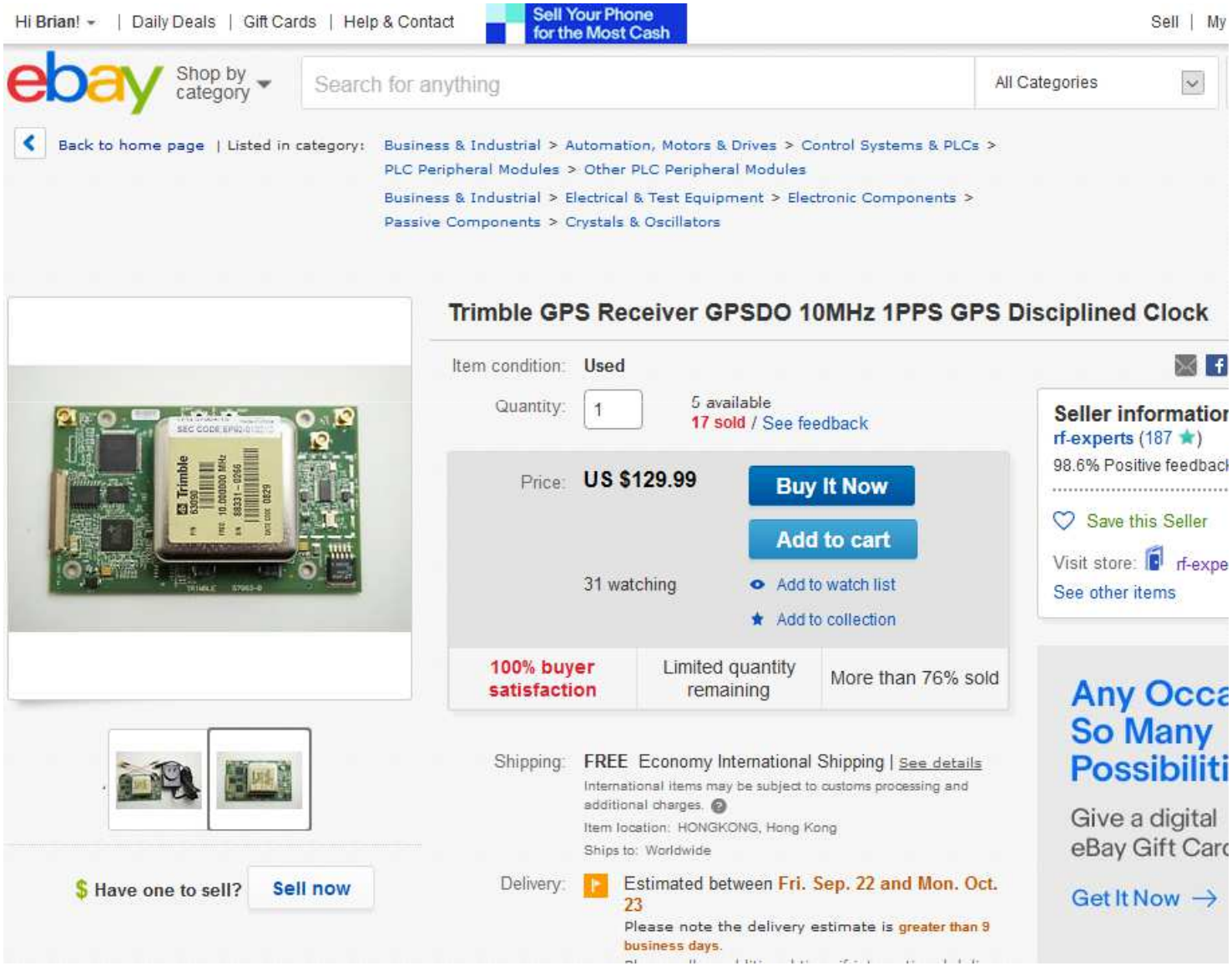
Rubidium Standard



GPSDOs HP Z3801A and Cousins

GPSDOs Trimble Thunderbolt

Ex-Telco Trimble GPSDO



Ex-Telco Symmetricom GPSDO

Cesium Beam Standards – Ouch!

ebay Shop by category | Search for anything | All Categories | Search

Back to search results | Listed in category: Business, Office & Industrial > Electrical & Test Equipment > Test, Measurement & Inspection > Other Test & Measurement

Mouse over image to zoom

Have one to sell? Sell it yourself

HP 5061B Cesium Beam Frequency Standard, Fully Tested and Guaranteed Working

Condition: **Seller refurbished**

| Add to

US $11,995.00

Approximately £9,098.15

Buy it now

Add to basket

Make offer

Add to Watch list

11 watching

Add to collection

Best Offer available | 100% positive Feedback

nectar Collect **5,000** Nectar points

Redeem your points | Conditions

Seller information

midwestate (503 ★)

100% Positive Feedback

Follow this seller

Visit Shop: Midwest ATE

See other items

Postage: **US $721.10 (approx. £546.95)** UPS Worldwide Expedited | See details

International items may be subject to customs

“Spares and Repairs” !!

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Back to search results | Listed in category: Business, Office & Industrial > Electrical & Test Equipment > Test, Measurement & Inspection > Other Test & Measurement

Mouse over image to zoom

Have one to sell? Sell it yourself

HEWLETT PACKARD HP / AGILENT CESIUM BEAM FREQUENCY STANDARD 5061B - SOLD AS IS

Be the first to write a review.

Condition: For parts or not working

Add to

US $2,499.99

Approximately £1,896.23

Buy it now

Add to basket

Make offer

Add to Watch list

3 watching

Add to collection

Experienced seller

Best Offer available

Seller information

dockguys (38004)

99.9% Positive Feedback

Follow this seller

Visit Shop: SURPLUS SELECT/DO

See other items

OCXO Pros and Cons

- ++ No settle time.
- ++ Simple
- ++ Low cost
- -- Accuracy ??

OCXO and DOCXO - Pros and Cons

- ++ Accuracy can be very good
- ++ Self contained
- -- Warm up / settling time
- -- Power consumption

Rubidium – Pros and Cons

- ++ Very accurate
- ++ Quick warm up ~ 2 to 4 minutes
- ++ Self-contained
- -- Power consumption
- -- Lamp Life decidedly finite

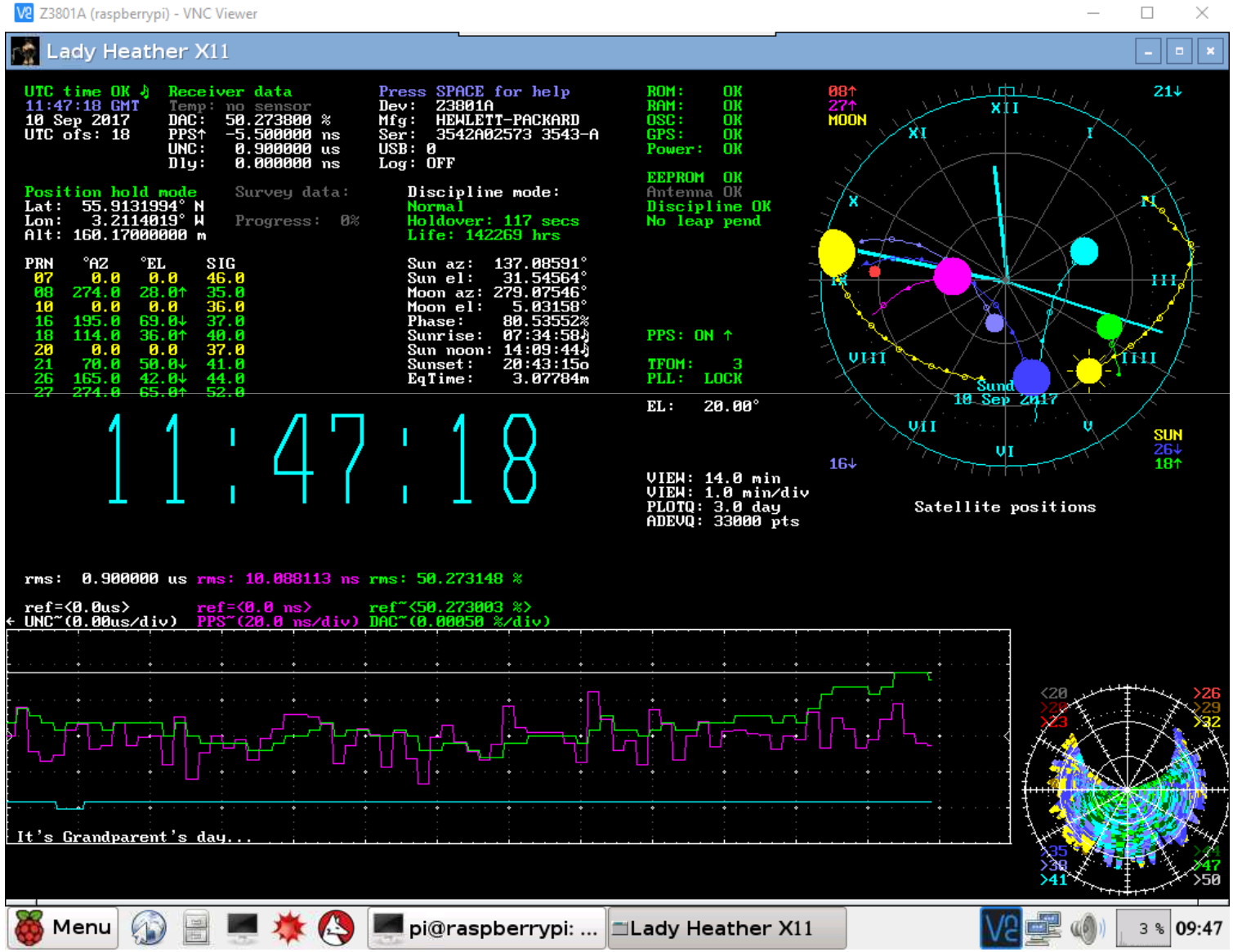
GPSDO – Pros and Cons

- ++ Very accurate
- ++ Moderate cost
- -- Power consumption
- -- requires an antenna with a sky view
- -- Settling time

Caesium Beam – Pros and Cons

- ++ Ultimate accuaracy
- -- Complexity
- -- Power consumption
- -- Cost … Ouch!!

Lady Heather control of GPSDOs



Lady Heather

- Written by Mark Sims (TexasPyro)
- Available on John Miles website (KE5FX)
- Desktop Icon ! 

Conclusions ??

- Shack standard - 10 MHz GPSDO
- Portable – Good TCXO or Rb