

Frequency (and Time) Standards

Brian Flynn GM8BJF

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 μ s	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

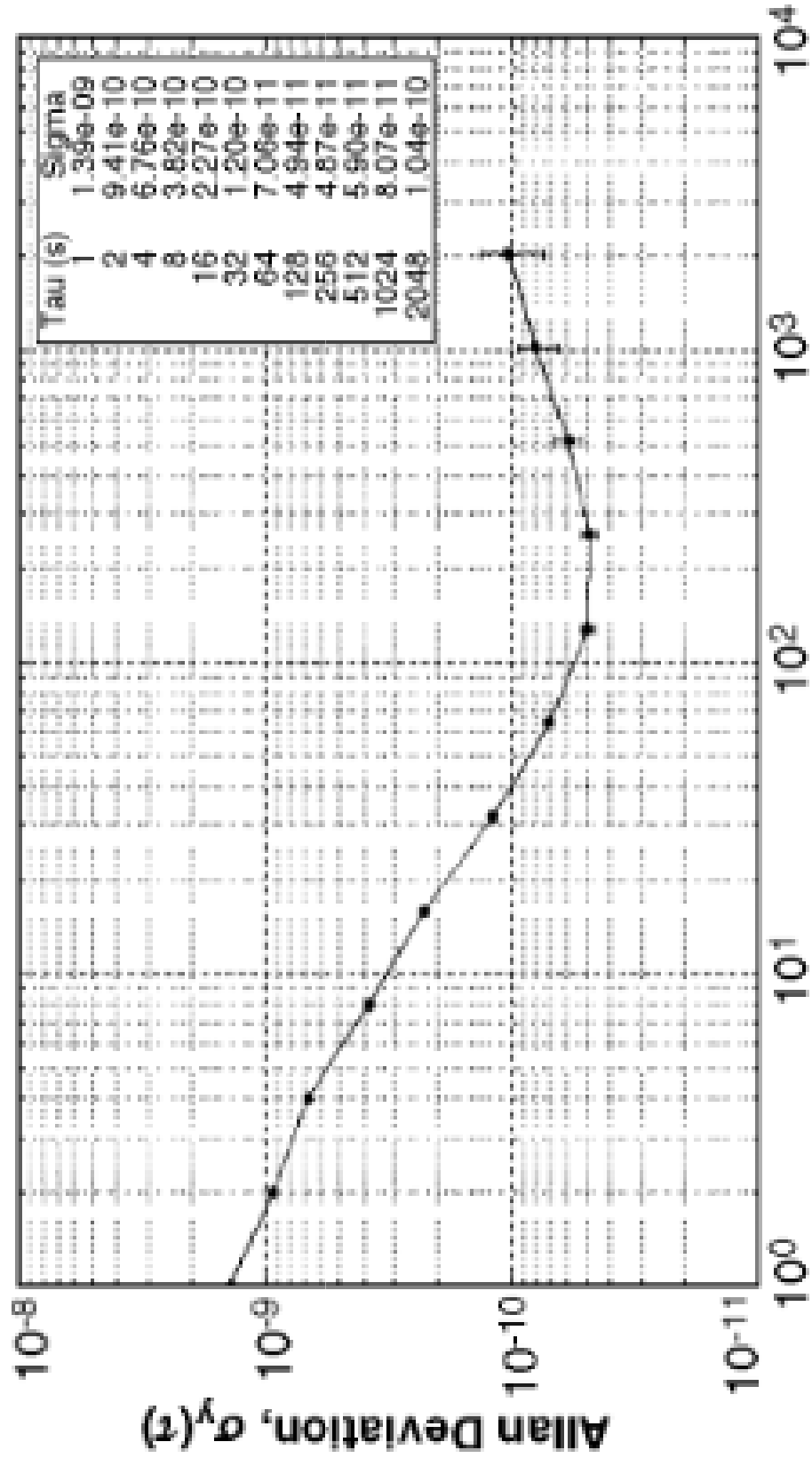
SI Base Unit	Physical Quantity	Uncertainty
Candela	Luminous intensity	1×10^{-4}
Kelvin	Temperature	3×10^{-7}
Mole	Amount of substance	8×10^{-8}
Ampere	Electric current	4×10^{-8}
Kilogram	Mass	1×10^{-8}
Meter	Length	1×10^{-12}
Second	Time interval	1×10^{-15}

Measurement Uncertainties and Allan Deviation

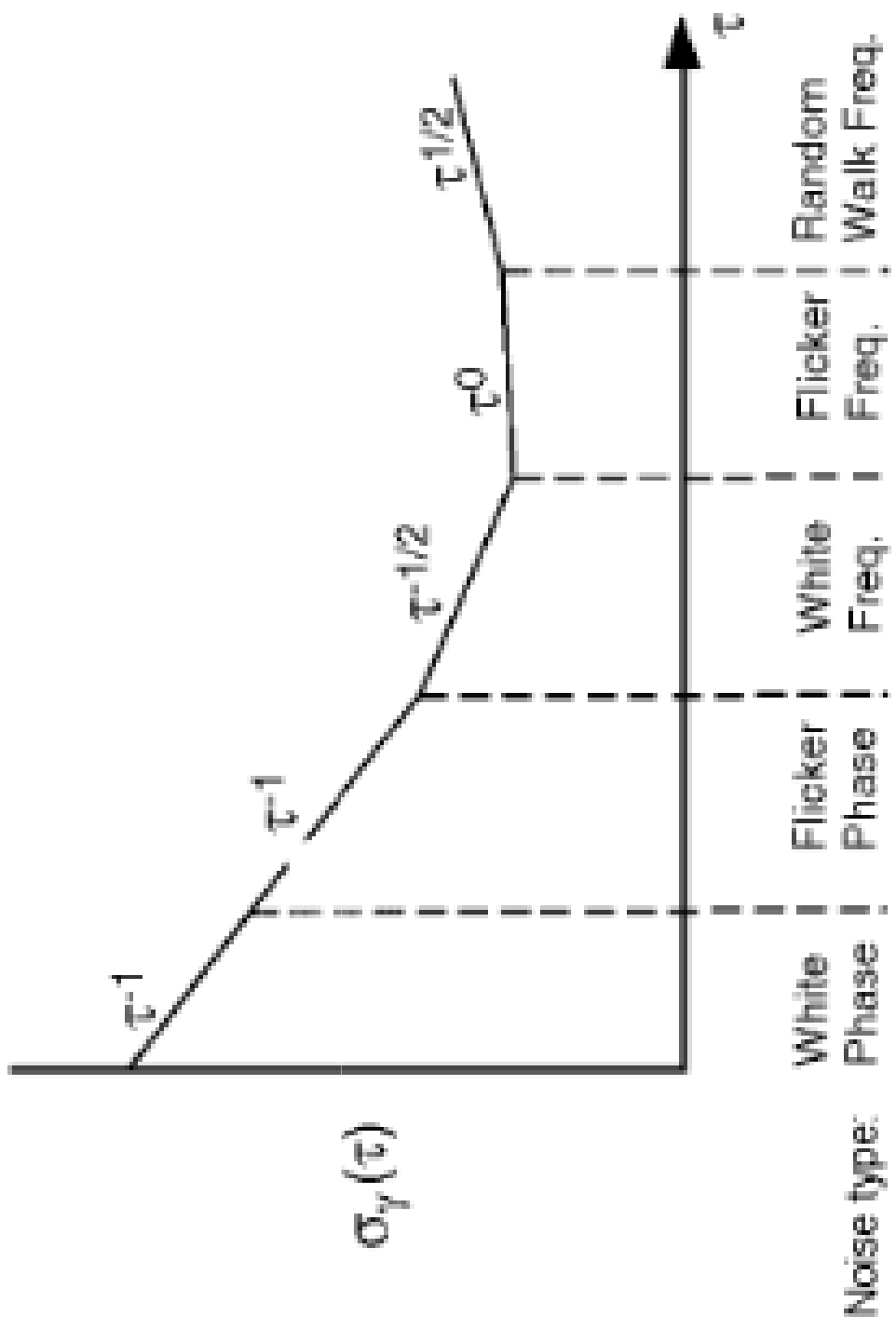
- All frequency sources have some degree of frequency variation. This can take the form of:
 1. Phase noise
 2. Amplitude noise
 3. Slow drifts or instability

Measurement Uncertainties and Allan 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.



Averaging Time, τ , Seconds



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	Duration	Acquired	Instrument
Trimble		9.999999974 MHz	1.060 s	4h 6m 2s	13926 pts	Hewlett Packard,5371A,0,2820
Symmetricon		9.99999970000001 MHz	1.060 s	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

Hello Brian. | Daily Deals | Sell | Help & Contact My eBay 

ebay Shop by category All Categories Ad

[Back to search results](#) | Listed in category: [Business, Office & Industrial](#) > [Electrical & Test Equipment](#) > [Test, Measurement & Inspection](#) > [Test Equipment Parts & Accs](#) > [Other Test Equip. Parts & Accs](#)



OCXO MV89A XO00281M-CT-MV89 10.0 MHZ Morion Double Oven Ultra Precision

Condition: **New other (see details)**
**Tested 100% OK before shipping.
Subscribe and follow us to get free tool/Discount/Gift.**

Production Year:


Quantity: More than 10 available
21 sold

£30.00

3 watching

21 sold | Experienced seller | 60-day returns


Ebay ID: Maxlzf2008

Seller information
maxlzf2008 (17042) 

98.6% Positive Feedback

Visit Shop: [maxlzf2008](#)
See other items

Registered as a business seller



Rubidium Standard

The screenshot shows a web browser window displaying an eBay listing. The browser's address bar shows the URL `www.ebay.co.uk/itm/Efratom-FRS-C-10MHz-Rubidium-Atomic-Oscillator-Frequency-Reference-Standard`. The page header includes the eBay logo, a search bar with the text "Search for anything", and navigation links. The listing title is "Efratom FRS-C 10MHz Rubidium Atomic Oscillator Frequency Reference Standard". Below the title, there are five stars and the text "Be the first to write a review.". The condition is listed as "Used" and the quantity is "1" (with "More than 10 available" noted). The price is "US \$199.99" (with "Approximately £151.69" noted). There are buttons for "Buy it now" and "Add to basket". A "Seller information" section shows the seller "testeque (9837)" with a 99.6% positive feedback rating and a "Follow this seller" button. A "Add to Watch list" button shows "1 watching".

Condition: **Used**

Quantity: More than 10 available

US \$199.99
Approximately £151.69

[Buy it now](#)

[Add to basket](#)

[Add to Watch list](#) 1 watching

[Add to collection](#)

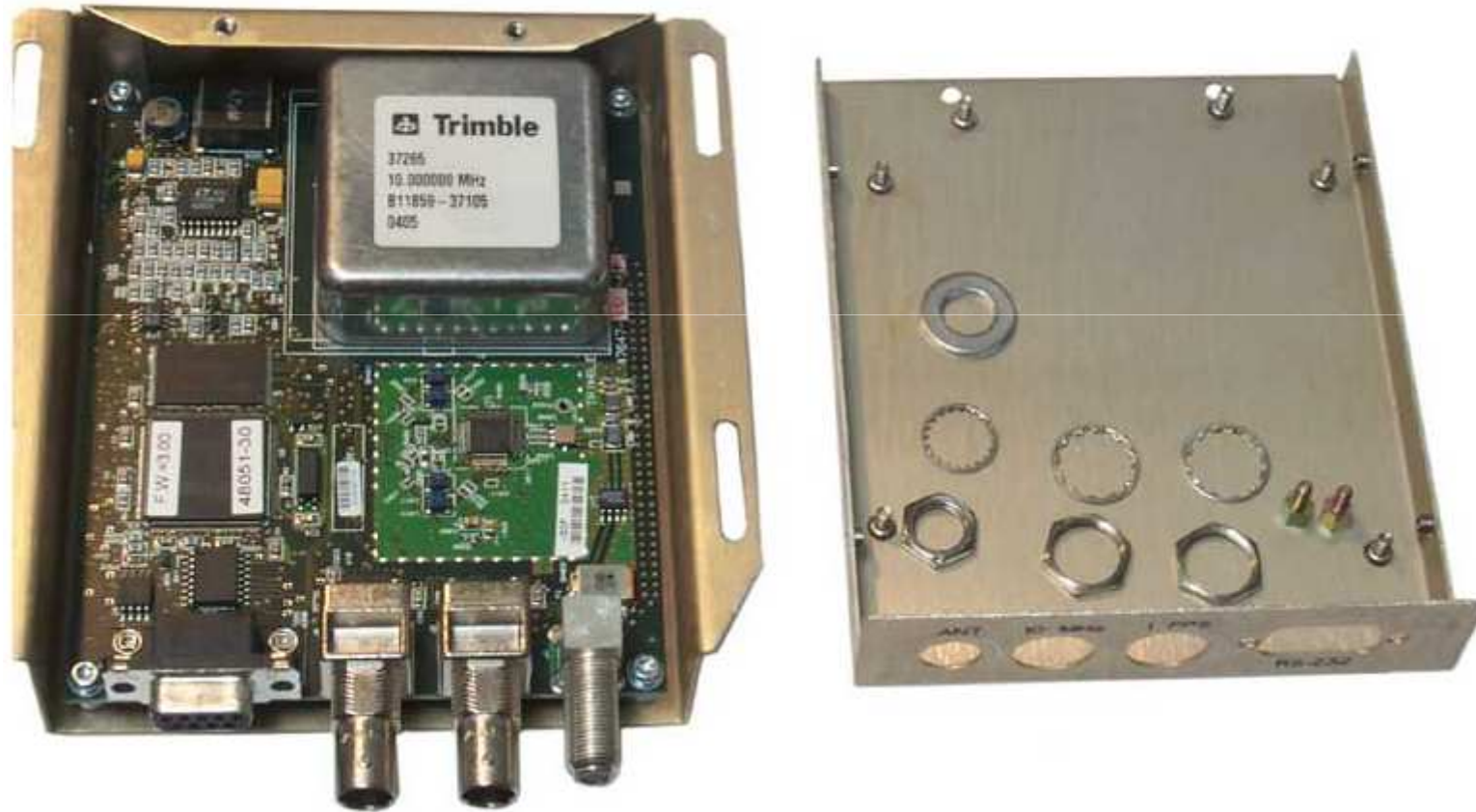
Seller information
testeque (9837) ☆
99.6% Positive Feedback
[Follow this seller](#)
Visit Shop: testeque
[See other items](#)

GPSDOs HP Z3801A and Cousins



HP Z3801A GPS Receiver

GPSDOs Trimble Thunderbolt



Ex-Telco Trimble GPSDO

Hi Brian! | Daily Deals | Gift Cards | Help & Contact

Sell Your Phone
for the Most Cash

Sell | My



Shop by category

Search for anything

All Categories

Back to home page | Listed in category: Business & Industrial > Automation, Motors & Drives > Control Systems & PLCs > PLC Peripheral Modules > Other PLC Peripheral Modules
Business & Industrial > Electrical & Test Equipment > Electronic Components > Passive Components > Crystals & Oscillators



Have one to sell? [Sell now](#)

Trimble GPS Receiver GPSDO 10MHz 1PPS GPS Disciplined Clock

Item condition: **Used**

Quantity:

5 available
17 sold / See feedback

Price: **US \$129.99**

[Buy It Now](#)

[Add to cart](#)

31 watching

[Add to watch list](#)

[Add to collection](#)

100% buyer satisfaction

Limited quantity remaining

More than 76% sold

Shipping: **FREE** Economy International Shipping | [See details](#)

International items may be subject to customs processing and additional charges.

Item location: HONGKONG, Hong Kong

Ships to: Worldwide

Delivery: Estimated between **Fri. Sep. 22 and Mon. Oct. 23**

Please note the delivery estimate is **greater than 9 business days**.

Seller information

rf-experts (187 ★)

98.6% Positive feedback

[Save this Seller](#)

Visit store: [rf-expe](#)

[See other items](#)

Any Occa
So Many
Possibiliti

Give a digital
eBay Gift Card

[Get It Now](#) →

Ex-Telco Symmetricom GPSDO



Cesium Beam Standards – Ouch!



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



US \$11,995.00

Approximately £9,098.15

Buy it now

Add to basket

Make offer

Add to Watch list

Add to collection

11 watching

Best Offer available

100% positive Feedback



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

Capacitive Pinch-Zoom-Swipe Touchscreen
Get deeper into your signals

SEE IT IN ACTION

Postage: US \$721.10 (approx. £546.95) UPS
Worldwide Expedited | See details
International items may be subject to customs
charges and additional charges.

“Spares and Repairs” !!



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

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

✉️ [f](#) [t](#) [p](#) | 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](#)

Seller information

[dockguys](#) (38004) ★

99.9% Positive Feedback

[+ Follow this seller](#)

Visit Shop: [SURPLUS SELECT/DO](#)

[See other items](#)

Experienced seller

Best Offer available

[Have one to sell? Sell it yourself](#)



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 accuracy
- -- Complexity
- -- Power consumption
- -- Cost ... Ouch!!

Lady Heather control of GPSDOs

Z3801A (raspberrypi) - VNC Viewer

Lady Heather X11

UTC time OK ↓
11:47:18 GMT
10 Sep 2017
UTC ofs: 18

Receiver data
Temp: no sensor
DAC: 50.273800 %
PPS↑: -5.500000 ns
UNC: 0.900000 us
Dly: 0.000000 ns

Position hold mode
Lat: 55.9131994° N
Lon: 3.2114019° W
Alt: 160.1700000 m

PRN	°AZ	°EL	SIG
07	0.0	0.0	46.0
08	274.0	28.0↑	35.0
10	0.0	0.0	36.0
16	195.0	69.0↓	37.0
18	114.0	36.0↑	40.0
20	0.0	0.0	37.0
21	70.0	50.0↓	41.0
26	165.0	42.0↓	44.0
27	274.0	65.0↑	52.0

Press SPACE for help

Dev: Z3801A
Mfg: HEWLETT-PACKARD
Ser: 3542A02573 3543-A
USB: 0
Log: OFF

Discipline mode:
Normal
Holdover: 117 secs
Life: 142269 hrs

Sun az: 137.00591°
Sun el: 31.54564°
Moon az: 279.07546°
Moon el: 5.03158°
Phase: 80.53552%
Sunrise: 07:34:50
Sun noon: 14:09:44
Sunset: 20:43:15
EqTime: 3.07784m

ROM: OK
RAM: OK
OSC: OK
GPS: OK
Power: OK

EEPROM OK
Antenna OK
Discipline OK
No leap pend

PPS: ON ↑
TFOM: 3
PLL: LOCK

EL: 20.00°

VIEW: 14.0 min
VIEW: 1.0 min/div
PLOTQ: 3.0 day
ADEVQ: 33000 pts

MOON 08↑
27↑

SUN 26↓
18↑

Satellite positions

11:47:18

rms: 0.900000 us rms: 10.088113 ns rms: 50.273148 %

ref=<0.0us> ref=<0.0 ns> ref=<50.273003 %>
+ UNC~(0.00us/div) PPS~(20.0 ns/div) DAC~(0.00050 %/div)

It's Grandparent's day...

Menu

 pi@raspberrypi: ...
 Lady Heather X11

3 % 09:47

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