GPS Disciplined Frequency Standards
Why Rubidium Outperforms OXCO based units
Don’t be confused by Allan Deviation Spec’manship

Update February 2016

While I stand by everything mentioned in this document, technology has moved on. Precision Test Systems now have a far superior frequency counter with 17 digits / second resolution. This has enabled us to make far more accurate measurements than shown below.

Our new GPS10eR (www.ptsyst.com/GPS10eR-B.pdf) has performance far better than our older unit the GPS10R mentioned in this document.

Original Document

Introduction

This article shows that the Rubidium based **G**lobal **P**ositioning **S**ervice **D**isciplined **O**scillator (GPSDO) offers superior performance than an OXCO based GPSDO, justifying the Rubidium’s higher price.

There are many types of frequency standards on the market. Recently the Global Positioning Service (GPS) has been used to “discipline” an oscillator to continuously calibrate it. These frequency standards offer excellent Allan Deviation results, comparable to Caesium oscillators at a fraction of the price. These frequency standards are known as GPS disciplined oscillators or GPSDO.

Generally two types of oscillators are used in these GPSDO’s, either a low cost oven controlled oscillator (OXCO) or a more expensive rubidium oscillator.

OXCO units can cost from $1000 up to $ 9000 while rubidium based units start from about $6000 to over $ 15000.

Allan Deviation Spec’manship

As already stated, rubidium based units can cost up to ten times the price of OXCO based units. However, when looking at the Allan Deviation specifications of both units, it seems an OXCO is just as good as a rubidium based unit.

This article will explain why this, generally, isn’t so. The article shows why rubidium based units offer much better accuracy than OXCO based units.

Definitions

<u>Allan Deviation is basically defined as:</u>

The statistical Deviation of the difference of two contiguous measurements.

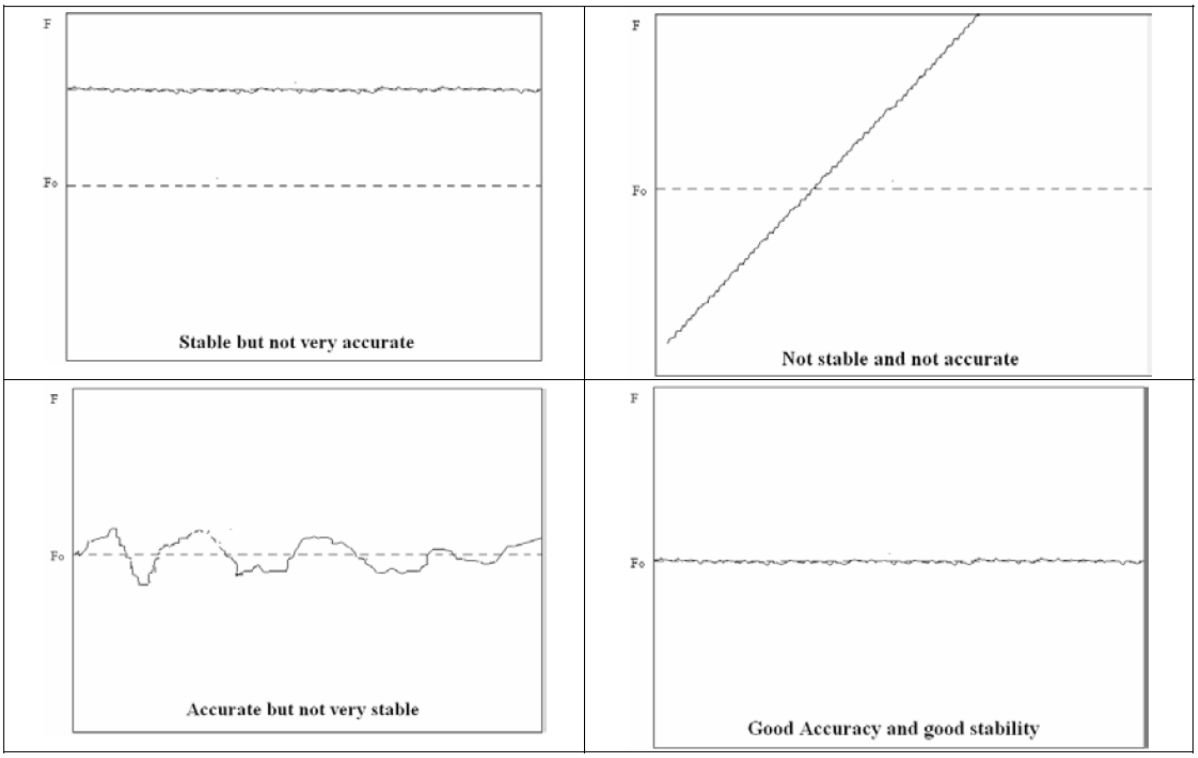
So Allan Deviation makes a measurement on a pair of samples and shows how stable an oscillator is, but not necessary how accurate it is.

Accuracy is basically defined as:

The degree of conformity of a measurement to a standard or true value.

Assuming we want a 10.000000 MHz oscillator. It is possible to have an oscillator that has very good Allan Deviation, but not very accurate, or an oscillator that has very good accuracy, but poor Allan Deviation.

Take a look at the four graphs below. © Hewlett Packard



Ideally we want an oscillator that has a good Allan Deviation and is also accurate as shown in the bottom right graph.

Why is Allan Deviation Important??

Allan Deviation is used my metrology organisations because they want very stable oscillators. These types of organisations don’t really care about ultimate accuracy, since they have the ability to accurately measure any offset and compensate for it. Allan Deviation is great and predicting whether an oscillator is going to be stable.

But end uses, i.e. customers, usually don’t have the ability to measure accuracy to close tolerances. This is why they need an accurate frequency source in the first place.

For example, the frequency standard may be used as the reference timebase for a frequency counter. The frequency counter makes measurements very fast, 1 ms to 10 sec, so a frequency standard that is accurate all the time is needed, not one that is just accurate if measurements are averaged over one week.

Actual Measured results

Measurements on two frequency standards, the GPS10RB Rubidium based, GPS disciplined frequency standard and an OXCO based, GPS disciplined frequency standard have been recorded below.

Although from reading Allan Deviation specifications, it seems the OXCO unit is a bargain (as it is cheaper), these results show the rubidium based unit offers far superior performance and its higher price is justified.

Allan Deviation Specifications

The published specifications of two units on the market are shown below, together with actual results measured by the author. The GPS10R is a GPS Disciplined, RUBIDIUM based frequency standard. While the other a GPS Disciplined, OXCO based frequency standard

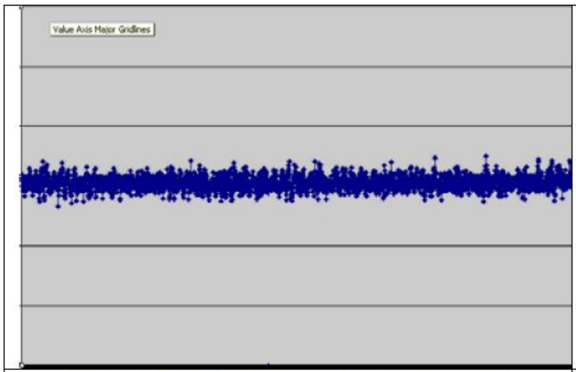
<u>Allan Deviation Results of both units as measured by the author:</u>

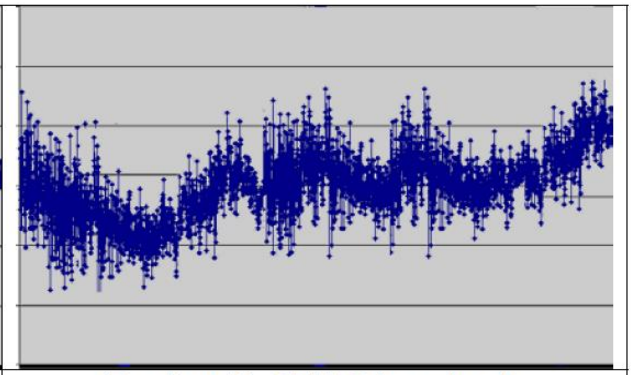
Averaging Time in Seconds	GPS10R Rubidium Based Unit		Product X OXCO Based Unit	
	Published Specs	**Measured Results**	**Design Specs**	**Measured Results**
0.01	Not Quoted	9.0×10^{-10}	5.0×10^{-11}	6.9×10^{-10}
0.1	Not Quoted	8.6×10^{-11}	6.1×10^{-12}	6.7×10^{-11}
1	2.0×10^{-11}	**1.2×10^{-12}**	**2.2×10^{-12}**	**1.28×10^{-12}**
10	1.0×10^{-11}	**5.3×10^{-12}**	**2.9×10^{-12}**	**7.9×10^{-12}**
100	2.0×10^{-12}	1.34 & 1.4×10^{-12}	5.3×10^{-12}	1.38×10^{-11}
500	1.0×10^{-12}	2.9×10^{-13}	8.5×10^{-12}	2.98×10^{-11}
> 1 week	**2.0×10^{-13}**		Not Quoted	**2 x 10E-13**

If we look at the results that are usually published by manufacturers, namely the Allan Deviation at 1 seconds and 10 seconds and one week (highlighted in red above) the low cost OXCO unit looks as good as the more expensive rubidium based unit.

However, if we measure the accuracy of each oscillator, at a one second gate time, the results look a lot different.

The results below were obtained by measuring the frequency of the same units on a high resolution frequency counter. The frequency counter has an absolute accuracy of 0.3 mHz or 3×10^{-11} in a one second gate time.





GPS10R Rubidium Oscillator unit	**Product X, OXCO based unit**
3600 measurements at 1 sec gate time.	3600 measurements at 1 sec gate time.

Vertical scale is 2 mHz (2 x 10^{-10}) / div   Vertical scale is 2 mHz (2 x 10^{-10}) / div

Conclusion of the above results

The rubidium based unit has accuracy better than ± 0.8 mHz or 8 x 10^{-11}.

The OXCO based unit has an accuracy of 5.8 mHz or 5.8 x 10^{-10}.

The above show that, although Allan Deviation specs are similar, the rubidium based unit is over **seven** times more accurate.

Summary of this article

Both a rubidium based GPSDO and an OXCO based GPSDO give outstanding accuracy for their price. However, the rubidium based GPSDO offers superior performance and should always be chosen when ultimate accuracy is required.

However, the OXCO version of the GPSDO still has a place in the market as its performance is often more than adequate for many customers' requirements.

Precision Test Systems manufacture both OXCO based and rubidium based GPSDO's.

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