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WHAT STABILITY IS REQUIRED FOR A LABORATORY REFERENCE?

When deciding for a reference for laboratory use several factors play a role. The most important parameters for the reference source are frequency accuracy and reference stability and in some cases phase-noise.

Most people believe that a Rubidium standard is the best answer but unfortunately this isn't always true.
One has to be careful to not get fooled by excellent Allan Variance numbers provided for Rubidium standards at very long measurement times. Since Allan variance only describes frequency fluctuations of the source over different observation intervals it does not reflect the absolute frequency accuracy.

For example an Allan Variance of $1*10^{-12}$ at Tau=100s would mean the frequency fluctuations of the reference source measured in 100s intervals would differ on average by only $1*10^{-12}$ even when the absolute error is in the $1*10^{-9}$ range.

In a typical electronics laboratory the most important measurements where accuracy is critical are frequency measurements. There are very few cases where a 1Hz accuracy at 10GHz isn't sufficient which translates into a reference accuracy of $1*10^{-10}$, a value easily achieved with the majority of the RF-SUISSE crystal oscillator based and GPS guided references. We can also assume most of the frequency measurements on a system are done with relative short gate times on the frequency counter or other test equipment.

Even more interesting is to compare the Allan variance of those references to typical Rubidium standards and one can notice that for the typical gate times for frequency measurements, usually <1sec, most if not all Rubidium standards are a lot worse! Sure, if the frequency averaged over 1000sec is crucial a crystal oscillator won't beat a Rubidium standard but who wants to wait that long for a frequency measurement? This is the reason why Rubidium standards are the best choice for timing applications but not as frequency references.

A real problem seen in many Rubidium reference applications is that they are used free-running. After only a relatively short period of time the standard will have aged enough to be a lot less accurate than the GPS guided RF-SUISSE references. The typical aging of a Rubidium standard is ~$1*10^{-8}$ within 3 months and that is for good ones. Less commonly known is that Rubidium based references are also sensitive to magnetic fields. Another problem of Atomic Clock based references is the potential for spurious close to the carrier due to the internal frequency lock loop.

The high-end timing TCXO GPS guided references like RS-GGO10-T2x, RS-GGO10-T3x (module) or RS-GGRS10-Tx (desktop/rack-mount) will satisfy the majority of uses in laboratory reference applications. Besides their much lower power consumption compared to Rubidium or OCXO solutions they have the advantage that they only need a few minutes after power-on to reach their specified accuracy. This makes them ideal for portable or mobile applications too and in a laboratory nothing has to be powered up while no-one is there.
In cases where a higher accuracy is required (i.e. $1*10^{-11}$) the RF-SUISSE OCXO based solutions provide another 10-fold improvement if one can accept that they should be powered all the time. For frequency measurement accuracy these references [RS-GGO10-Ox (module), RS-CGGO10-O (connectorized module) and RS-GGRS10-Ox (desktop/rack-mount)], provide short term accuracy usually not achieved by Rubidium standards. This provides accuracy sufficient to measure 0.1Hz at 10GHz! Most frequency counters won't even be able to provide this resolution due to limits in their internal logic caused by rise and fall times and jitter caused by their internal reference. They may display 12 digits but only some of them are accurate.

As RF-SUISSE concentrates on the RF and not the timing market it was decided that no Rubidium standards will be offered (ignoring the fact that Switzerland is known for its timing industry).

Now to the critical question: how can one measure the frequency accuracy of a reference? The answer, as always, is “it depends”. If a more accurate reference is available this reference can be used to lock a high performance frequency counter. However, once $1*10^{-10}$ is exceeded it is getting difficult unless a Maser is at hand which usually isn't the case. For absolute frequency

measurements, a good timing reference available is the 1PPS pulse out of a GPS receiver. Averaged over a day, an accuracy of down to $2*10^{-14}$ is achievable. Unfortunately the Allan Variance of a good receivers 1PPS output at 1sec is only at around $1*10^{-8}$. Therefore phase locking the reference to a GPS signal will ensure the long term average of the source frequency is accurate. Then for the short term stability the only option is use two identical references. One is used as a reference for a high performance frequency counter and the other one is measured with this counter. Assuming similar behavior of the two sources, the resulting error can then be divided by sqrt(2) to calculate the real value for one reference.

Conclusion: the timing industry will naturally always prefer Rubidium or Cesium based standards but for accurate frequency measurements crystal oscillator based GPS guided solutions are the better way to get accurate. In addition all the disadvantages of these timing standards like aging, lifetime, temperature sensitivity and power consumption can be avoided.

RF-SUISSE provides the following GPS guided crystal based references:

Modules		Enclosure	
RS-GGO10-T2P	TCXO based, 1PPS input	RS-CGGO10-T	connectorized RS-GGO10-T2 with GPS
RS-GGO10-T2G	TCXO based, GPS receiver	RS-CGGO10-O-GPSx-yyy	connectorized RS-GGO10-O with GPS
RS-GGO10-T3P	high performance TCXO, 1PPS input	RS-CGGO10-O-PPS-yyy	connectorized RS-GGO10-O with optical 1PPS
RS-GGO10-T3G	high performance TCXO, GPS receiver	RS-MRGGT10	Small TCXO based laboratory reference
RS-GGO10-O	OCXO based, 1PPS input		
RS-GGO10-OG	OCXO based, GPS receiver		
RS-CGGO10-T	connectorized RS-GGO10-T2 with GPS		
RS-CGGO10-O	connectorized RS-GGO10-O with GPS		

For the latest product information, data-sheets and application information please visit our website at http://www.rf-suisse.ch

Recommendations:

Normal laboratory use: a TCXO based solution (all the above -T models) will give the required accuracy and as they don't need to be permanently powered they are energy saving too. The -T3 models almost meet the same specifications as an OCXO and in a lot of cases they will even be usable for standard calibration purposes.

Standard calibration: an OCXO based solution (all the above -O models). We strongly recommend to power these units from an UPS to make sure that power glitches don't impact the performance.

If a time accuracy of <1μsec after 3 months under water is important: by all means use a GPS guided Rubidium standard as this is a timing solution but most likely not the ideal frequency reference.

As we continuously improve our product we reserve the right to change published specifications without further notice.
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