The Calnex Sentinel's Rubidium offers best-in-class holdover performance enabling accurate sync test in the field when there is no GPS signal available. This FAQ explains some of the features of Sentinel's Rubidium and how to discipline it to ensure accurate timing while in holdover.

FAQ: Rubidium Holdover and Disciplining

1. What is holdover mode?

An operating condition of a clock which is no longer locked to an input reference. In holdover, the clock maintains the same frequency and phase from when it was last locked to a reference.

Holdover begins when the clock is disconnected from the input reference. On Sentinel, that means when the GPS or the external 1pps input has been removed.

Holdover terminates when the clock locks to a new reference input. On Sentinel, that means when the GPS or the external 1pps input has been restored, and the Sentinel has re-locked to the input.

2. What is transport mode?

A mode of Sentinel in which the internal battery is used to keep the Rubidium oscillator powered and in holdover mode when the main power supply is removed. In this mode, the rest of the instrument is powered down and the battery only provides power to the Rubidium. On Sentinel, transport mode is only available if the battery option is installed. Transport mode can be enabled upon switching off the instrument.

3. What performance can I expect in holdover?

After being disciplined, the Sentinel Rubidium will typically maintain accuracy to within 200ns for 12 hours after entering into holdover state. Note that the actual duration depends on the status of the Sentinel Rubidium before it is put in holdover mode. Additionally, environmental conditions such as temperature changes and magnetic field change may also impact the performance obtained.

4. Is regular return-to-factory calibration required for the built-in Rubidium?

No, regular return-to-factory calibration is not necessary for the Sentinel's Rubidium.

Sentinel is equipped with a GPS receiver and the built-in Rubidium can be disciplined by connecting to GPS (or an external 1pps reference) for a period of time – see below. During this process the Rubidium disciplines to the supplied reference and the software stores the value of the disciplining process. On power up the Rubidium will always use the most recent stored value.

5. How long should I discipline the Rubidium with GPS before use?

This depends on the last time Sentinel was disciplined by a reference. We recommend the following minimum disciplining durations:

• If last disciplining was < 1 week ago – discipline for a minimum of 6 hrs
• If last disciplining was > 1 week ago – discipline for a minimum of 12 hrs

If the recommended minimum disciplining durations are met, the Sentinel's Rubidium will become stable and will be accurate to the product specification. If not, then its performance may not be as accurate and may be hard to predict.

6. What other signals besides GPS can be used to discipline Sentinel?

An external 1pps signal can also be used to discipline the Sentinel Rubidium. If the source of the 1PPS is GPS or an external Rubidium oscillator, the same minimum disciplining durations are recommended as per disciplining using GPS. If a Caesium oscillator is used then disciplining for 1 hour is sufficient. Note that any external 1pps reference used to discipline Sentinel should be high quality.

7. Why does disciplining the Rubidium take so long?

To correct the offset of a Rubidium from a reference source, the Rubidium internal control system needs to adjust its oscillator frequency gradually to match to the reference. To ensure a very accurate final alignment the adjustment steps are small and therefore the bigger the initial frequency offset from the reference the longer it will take.

Secondly, GPS is inherently noisy over the short term (up to a few hours), but very accurate over the long term (12 hours or more). Therefore, disciplining to GPS needs to take a long time to get accurate results.

If the Sentinel Rubidium was last disciplined a week ago, the initial frequency offset will be larger and that is why a minimum of 24 hours disciplining duration is recommended. If it was last disciplined within a week, the offset will be smaller, therefore a shorter disciplining duration is required. It is a trade-off between accuracy and time to discipline.

8. Can I discipline Sentinel for less than the recommended duration before use, for example, two hours?

If the above recommended minimum disciplining durations are met, we know the Sentinel Rubidium will become stable and will be accurate within the product specification. If disciplined for less than the recommended duration, then its performance may not be as accurate. It is hard to predict the frequency of the Rubidium in this instance and therefore the performance.

9. Which setting should I choose for "the internal reference disciplining mode"?

We recommend it is set to "always" while a valid reference is available and connected, for example, a GPS signal or external 1pps signal. It should be set to "never" if operating in holdover mode.

10. How many satellites are needed by the GPS receiver to obtain lock?

At least three satellites are required for the GPS receiver to obtain position fix and timing information. The status of satellite connections can be viewed on the Sentinel GUI.

11. What is the "survey status" displayed on the Sentinel GUI for and how long will it take?

The self-survey is a process for the GPS receiver to solve system parameters such as baselines, integer ambiguities, line biases, and attitude, etc. It normally takes around 30mins from cold start. When Sentinel is booted up with GPS connected, the GPS receiver starts to perform a self-survey. Once the self-survey is complete and Sentinel is locked to at least three satellites, the GPS satellite icon will turn green and the GPS receiver will start outputting a 1pps signal.

12. Why does the antenna status display a fault although Sentinel locks to one or more satellites?

The antenna status displays a fault if the antenna is not powered by the Sentinel, i.e. a splitter is connected in-between the antenna and the Sentinel.

13. What do the icons at the bottom of Sentinel's GUI mean?

Refer to the table overleaf.

GUI ICON	DESCRIPTION
INT REF	**Timebase reference status:**
	Internal Rubidium is used as Timebase Reference
EXT REF	External signal is used as Timebase Reference
Rb	**Rubidium status:**
	Rubidium is ready
Rb	Rubidium is warming up
Rb	Rubidium is not ready or Rubidium malfunction detected
🔒	**Rubidium disciplining status:**
	Rubidium is disciplining and locked with a phase offset less than ±100ns
🔒	Rubidium is disciplining and locked with a phase offset greater than ±100ns
🔓	Disciplining is off. Either disciplining mode is set to "Never" or disciplining mode is set to "Not during measurement" and measurement is currently in progress or GPS is the disciplining source and GPS is not locked to at least three satellites
🔓	Rubidium is disciplining and acquiring phase lock
🔓	Disciplining is turned on, but no valid disciplining signal is present
1PPS	**Ext 1PPS status:**
	External 1PPS is present and is generating a valid 1PPS signal. Icon turns clear when Rb is in manual holdover mode
1PPS	External 1PPS is either not present or is not generating a valid 1PPS signal. Icon turns clear when Rb is in manual holdover mode
🛰️	**GPS status:**
	GPS malfunction
🛰️	GPS is locked to at least three satellites and site survey is complete
🛰️	GPS is not locked yet, but some satellites are visible
🛰️	No antenna or no visible satellites
🔋	**Battery status:**
	Battery is not installed
🔋	Battery is installed and charging (charge percentage is indicated next to battery icon)
🔋	Battery is installed and not charging. Battery will not charge when 100% charged, or while Rubidium is warming up or if the battery temperature is less than 0°C or greater than 45°C
🔋	Battery is installed, error has occurred reading battery controller or a battery fault has been detected