Rubidium Frequency Standard

A Rubidium frequency standard owes its outstanding accuracy and superb stability to a unique frequency control mechanism. The resonant transition frequency of the Rb87 atom (6,834,682,614 Hz) is used as a reference against which an OCXO output is compared. The OCXO output is multiplied to the resonance frequency and is used to drive the microwave cavity where the atomic transition is detected by Electro-optical means. The detector is used to lock the OCXO output ensuring its medium and long-term stability.

The first realised Rb frequency standard arose out of the work of carpenter (Carpenter et al 1960) and Arditi (Arditi 1960). It was a few years until the first commercial devices came onto the market and this was primarily due to the work of Packard and Schwartz who had been strongly influenced by the work of Arditi a few years before on Alkali atoms (of which Rb87 is one). Unlike much of the research done into frequency standards at that time, practical realisation of a rubidium maser was high on the researchers agenda. This was mainly due to an understanding that such a device would have extremely good short-term stability relative to size and price. In 1964, Davidovits brought such research to fruition, with the first operational rubidium frequency standard.

The rubidium frequency standard, like its more expensive cousin, the hydrogen maser, may be operated either as a passive or as an active device. The passive rubidium frequency standard has proved the most useful, as it may be reduced to the smallest size whilst retaining excellent frequency stability. The applications for such a device abound in the communication, space and navigation fields.

The rubidium frequency standard may be thought of as consisting of a cell containing the rubidium in its vapour state, placed into a microwave cavity resonant at the hyperfine frequency of the ground state. Optical pumping ensures state selection. The cell contains a buffer gas primarily to inhibit wall relaxation and Doppler broadening. The Rubidium frequency standard essentially consists of a voltage controlled crystal oscillator, which is locked to a highly stable atomic transition in the ground state of the Rb87 atom.

There are several reasons why Rb has an important role to play as a frequency standard. Perhaps most importantly is its accuracy and stability. Accuracy is comparable with that of the standard caesium with an operating life approximately 5 times that of Cs. Furthermore, the cost of a replacement physics package is only about $50 or even free. Moreover the stability of Rb frequency standard over short time-scales -100s of seconds- betters that of Cs (Cs are more stable over longer time periods, in the regions of hours to years). After 100s the frequency stability of the best performing Quartzlock Rb is 3.10^{-13}, better than the HP standard caesium beam tube. The phase noise of the Quartzlock Rb is -150 dBc/Hz @ 10 kHz from the carrier, identical to the HP5071 which provides 80 % of the UTC weighting.

There are, however, a few drawbacks to the use of Rb as a frequency standard. In the past, these included the limited life of the Rb lamp (since improved to >10years), The Caesium is affected to a greater degree than this, whilst the H-maser operates differently and is not affected. The thermal stability of Rb is inferior to that of Cs or H-Masers, and the Rb previously required frequency access to a primary reference signal or synchronisation source to maintain long-term Cs level accuracy.

The cost of a rubidium frequency standard at around $5000 is significantly cheaper than a Cs, with a much reduced size and weight (The HP5071 weighs about 30kg). Due to its small size, low weight and environmental tolerance the Rb frequency standard is ideal for mobile applications. Indeed, Rb atomic clocks are beginning to be implemented into the new generation of GPS satellites. This is in part due to the extended life of the Rb physics package c.f. Cs. The Rb is also extremely quick to reach operational performance, within 5mins reaching 5 parts in 10^{10}. The Quartzlock A-10-B is the only rubidium frequency standard providing the user with 1MHz, 5MHz and 10 MHz sinewave and squarewave outputs from the front panel. Also included on the front panel is a 1pps output, enabling the user to turn the Rb frequency standard into a clock.. At the rear of the device, a 10MHz @ 7dBm highly buffered core output is provided. Although these 10 MHz outputs at the back specify 10MHz, simple alterations within the unit, (easily performed by even the novice) can turn this into either 5MHz or 1MHz. The flexibility afforded by the A-10-B is unsurpassed. Due to Quartzlocks wide range of products and expertise, a further improvement is possible using the Quartzlock A8 carrier phase tracking GPS. By inputting a signal from the A8 GPS to the rear of the unit, the A-10-B may be transformed into an extremely accurate and stable GPS disciplined Rubidium.

Recently Quartzlock have been awarded a major European research and development award. The CRAFT project will, amongst other things, enable further research and development of the companies Rb frequency standard. Already an entirely new electronics package has been developed in Falmouth. It is hoped that the Quartzlocks production of Rubidium will expand rapidly within the UK from 60 units/year to over 1000/year. This will enable it to become one of only three companies serving the world market for Rb standards (at present worth ~$100 million).

Naturally, the applications for such a low cost, small size device with excellent short-term accuracy abound. It may be used in frequency calibration, telecom network synchronisation, cellular phone base stations, satellite navigation and GPS receivers, TV broadcasting, radio transmitters, ground and satellite communications, time base and calibration, secure communications and spread spectrum techniques and radio navigation.