RUBIDIUM ATOMIC CLOCK WITH DRIFT COMPENSATION

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Abstract

This paper shows the results of an automatic system that compensates drifts of rubidium atomic clocks, comparing to GPS. This leads to high stability in large time and low noise in short time.

Introduction

Rubidium atomic clocks are not primary standards because their frequencies change in time due to internal and external influence sources. The main one is the buffer gas they have, necessary for the operation. This gas reduces the velocity of the rubidium molecules, reducing the internal noise; but the variation of its content changes the output frequency.

Electromagnetic interference is one of the mayor external influence factors. Although these devices are shielded against external fields, some influences remain, and also fields produced by the device itself can affect the frequency [1]. On the other hand, these clocks are much cheaper than cesium clocks, and their short-term internal noise is very low, in the order of 3×10^{-12} Hz/Hz in times of 100 s (see Fig. 1).

Another type of clock, called GPSDO (GPS disciplined oscillator) has a GPS connection that controls the oscillator (generally of rubidium type) [2]. In long term, this type of clock does not have drift, because the GPS system is controlled by a large number of cesium atomic clocks. However, commercial GPSDOs have high noise in short term, as Fig. 2 shows. Each vertical division represents 5 parts in 10^{11}.

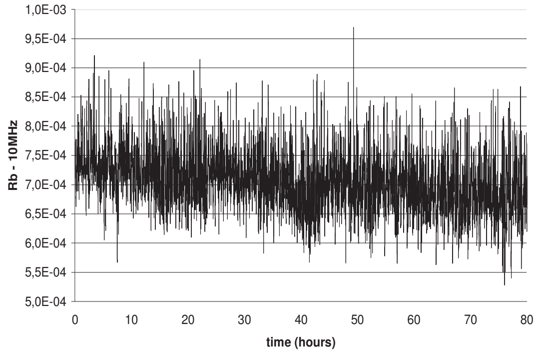

Figure 1: Noise and drift of a free running rubidium clock.

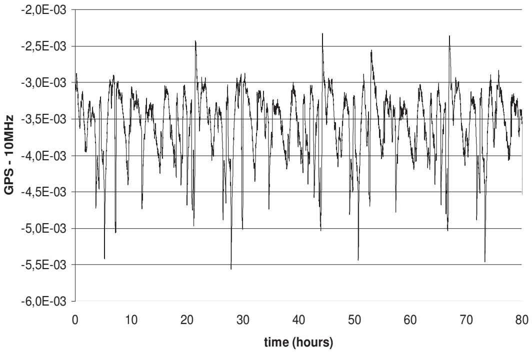

Figure 2: Noise of a commercial disciplined rubidium clock (GPSDO). Vertical scale: 5×10^{-11} Hz/Hz.

Proposed system

The proposed system is formed by a GPSDO, a rubidium clock, a universal counter and a computer that controls all the system. Fig. 3 shows a block diagram of the system. The output frequency (10 MHz) of the rubidium clock can be lightly changed by a control voltage. This voltage is generated using a reference zener, a high precision resistive divider (Vishay resistors) and a 16 bits digital to analogue converter (DAC). A microcontroller (PIC) sets the data in the DAC according to the computer control, via RS232. The rubidium oscillator, the control circuit and the microcontroller are inside a box (Frequency Standard Rubidium). An analogue divider (4:1) is needed to adapt voltages. A frequency divider generates 5 MHz, 1 PPS and a selectable decade values from 1 Hz to 10 MHz.

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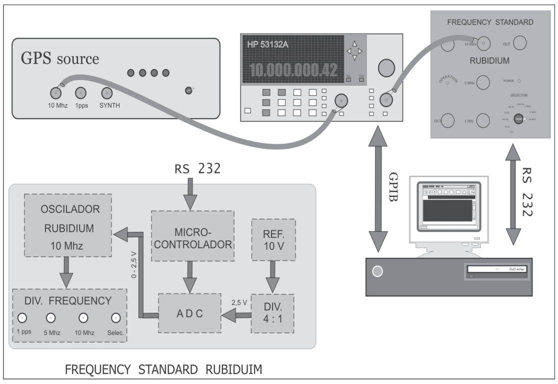

Figure 3: Block diagram of the proposed clock.

The universal counter measures the phase difference between the signals of 1 PPS generated by the GPSDO and the rubidium clock. The computer program evaluates the phase difference and a mathematic algorithm calculates the correction. This correction is applied in such a way that does not generate large steps in frequency.

Details on the control algorithm will be presented at the meeting.

Results

Fig. 4 shows the behavior of the phase difference between the rubidium and a GPSDO clock during one month. Most of the time is under ±20 ns.

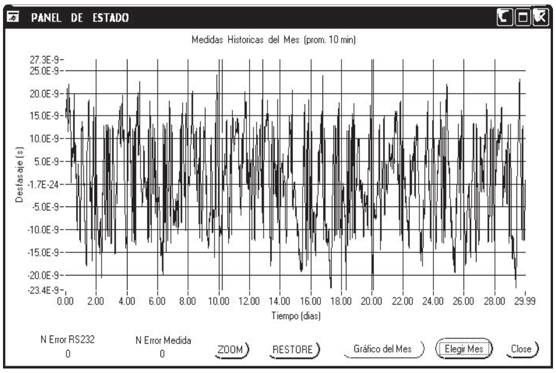

Figure 4: Phase difference between the rubidium and GPSDO clocks.

An intercomparison against NIST was done during November and December of 2009, through the SIM System (see Fig. 5). Some values were lost. This system allows to compare clocks of National Metrology Institutes (NMI). The differences were below ±15 ns of its average value. The Allan deviation can be reduced to 1.2 ns, averaging 4 days of measurements. The deviation is not significantly reduced if we average more of 4 days (see Fig. 6).

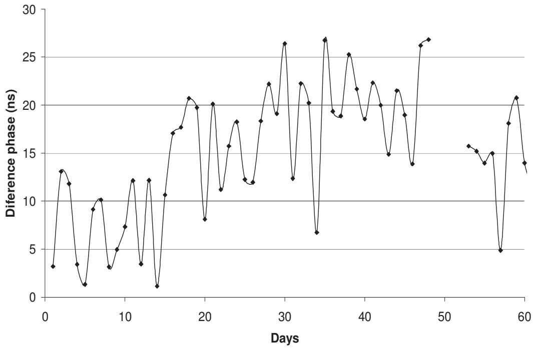

Figure 5: Phase difference between UTE-NIST.

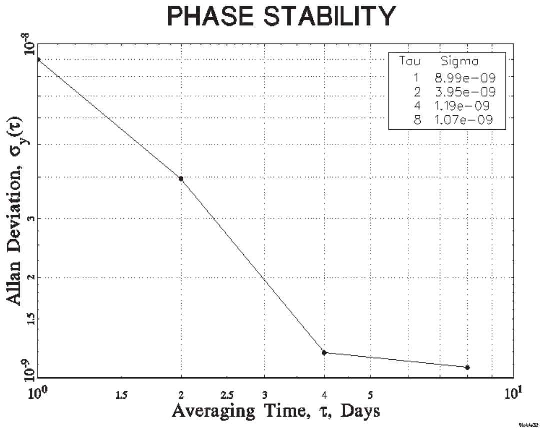

Figure 6: Allan deviation of the phase difference UTE-NIST.

Conclusions

A system that has the low short-term-noise of rubidium clocks and no drift of GPS systems was described. Its cost is ten times lower than a cesium clock, allowing many applications where these requirements are relevant.

More information will be presented at the meeting.

References

[1] SIM, Seminario Metrología, "Principio de funcionamiento relojes atómicos de rubidio," Buenos Aires, Feb. 2008.

[2] Spectratime, *model GPSource manual.*

[3] Spectratime, *model RM manual.*