Next Step For Delivery Of Precise Frequency and Phase OCXO For "5G" Telecom and Beyond

Jean-Charles BILLEBAULT, Didier THORAX, Nicolas GUFFLET, Alexander KOVACH, Vincent CANDELIER, Hamdi HENCHIRI, Ullas KUMAR, Frédéric VITTRANT

RAKON France SAS / 10, Avenue des Louvresses – Business Park « Carré-92 »
92230 GENNEVILLIERS – France
e-mail : vincent.candelier@rakon.com

Abstract— New "5G" telecom market requirements and further "6G" emphasise the need for highly stable and reliable devices, capable to deliver time-phase and frequency stability, allowing precision over 1 day and more.

This paper presents how Rakon deal with the various challenges for reaching the required levels of performance on his OCXO platforms with an industrial approach, an analysis of these OCXO platforms and related performances, taking account of the customer request. We explain the different possibilities of using the product during the holdover period.

I. Introduction

The new RAKON smart OCXO platforms deliver an overall high stability solution and provide a competitive alternative to existing devices, adapted to the new infrastructure-architecture of the networks.

Industrialization and process control improvements of recent designs, using thermal simulation tool [2] and digital filtering, have made possible a cost effective solution which reaches very high levels of performance using standard and industrial structures and readily available components.

II. Methods/Results

In a previous paper [1], we presented two solutions to respond to the requirement of 1.5us holdover time over 24H (see figure 1). The two platforms are the ROD3827T2 and the ROD5242T1. They are based on a smart OCXO which is with a very low frequency versus temperature sensitivity and which is able to compensate the residual thermal variation and the ageing using a microcontroller. Otherwise the OCXO can also be used only as a digital frequency controlled OCXO (NCO) or as an NCO plus additional phase measurement between the NCO pps output signal and the input pps signal provided by the customer. Different status information can also be fetched by the module. The ROD5242T1 performances in temperature (figure2) are better than the ROD3827T2 one's (figure 3)

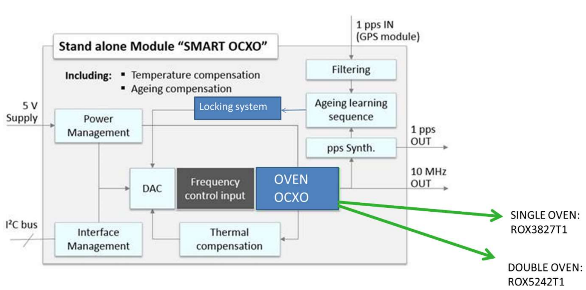

Fig. 1. OCXO module structure

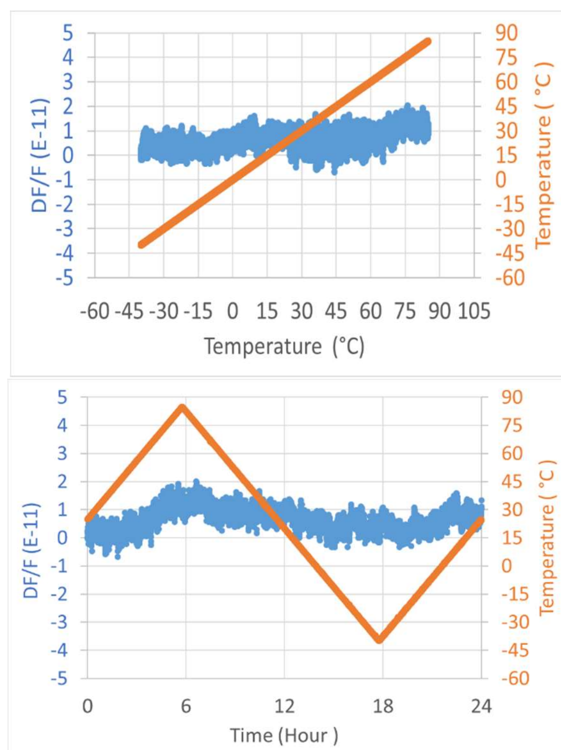

Fig. 2. ROD5242T1 Thermal relative frequency variation with 10°C/Hour in (-40°C 85°C),
(top view: hysteresis, bottom view: versus time).

because of its double oven structure compared to latest which has a single oven structure.

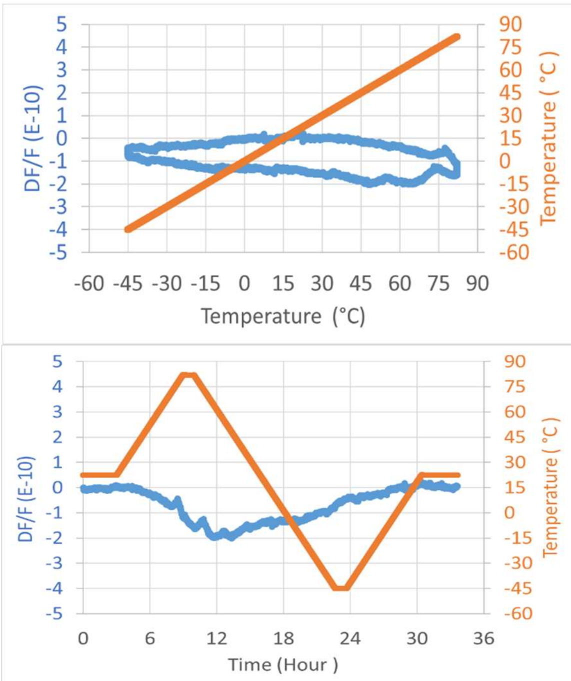

Fig. 3. ROX3827T2 Thermal relative frequency variation with 10°C/Hour in (-40°C 85°C),
(top view: hysteresis, bottom view: versus time).

For compensating the ageing during the holdover time, the OCXO learns its ageing using its frequency control variation during a phase "locked" state in which it is tightly tracking the phase of an input pps signal coming from a GPS receiver or an atomic clock. The block diagram of the states is presented in figure 4.

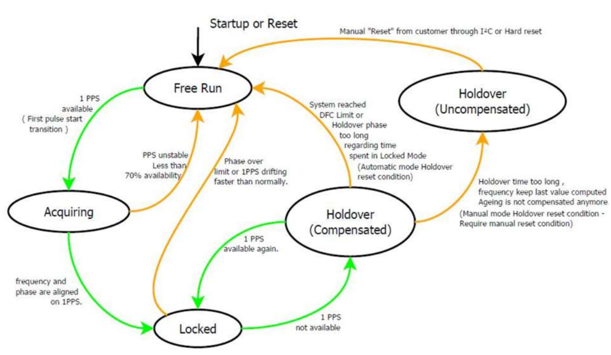

Fig. 4. ROD5242T1 learning ageing states diagram with 5 main steps : 1/Free run, 2/acquiring, 3/locked and learning, 4/holdover (compensated), 5/holdover(uncompensated).

After a "free run" period for the warm up, when the pps is available, the OXCO goes through a self-calibration state. After this, a quick algorithm is run in "acquiring" state to lock rapidly in phase the OCXO (see figure 5a) on the input reference. After 30 min, it passes in the "locked" and ageing learning mode and the GPS noise is filtered. It takes 4 hours to come to a TIE less than 50ns (see figure 5b). The acquisition time has to be twice the holdover time we want to guarantee. This way, we can withstand 24H of holdover with 48H of learning. Different scenarios will be discussed later, to follow all the events which can be seen by the product. During all the life of the product, a bit pin can provide an alarm signal when the supply is unstable, the current is too high, the TIE is upper a specified value, the frequency failed, the clock doesn't start or the frequency control voltage is too high or too low. A register in the OCXO is available by I2C bus to analyze that if multiple events appear at the same time.

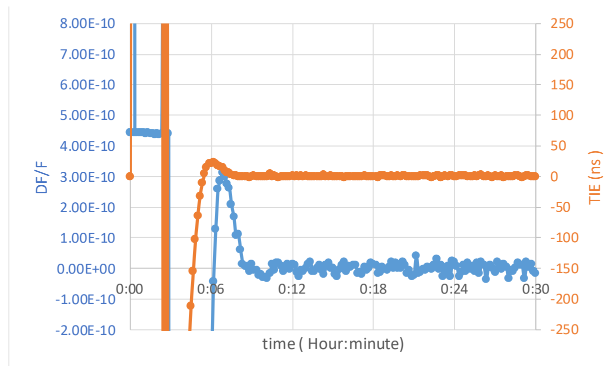

Fig. 5a. ROD5242 first 30 minutes of the acquiring state

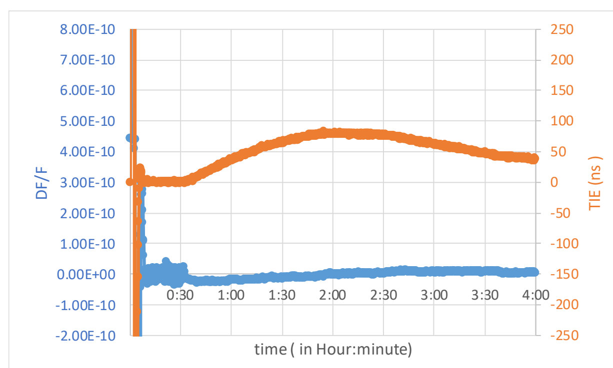

Fig. 5b. ROD5242 The first 4H of the locked state following the 30 minutes of the acquiring state.

To validate in production the holdover performance, we have developed a new system called MOBSAC, which can measure in parallel 196 parts [1]. The resolution of the relative frequency variation measurement is 6E-13, which is enough to measure any relative frequency jump upper than 1.75E-11. That is the maximum value to guarantee the holdover of 1.5us over 24H. A worst case profile scenario is presented in figure 6, showing the maximum possible impact of the temperature on the holdover. The part has learnt the ageing during 72H and has applied an ageing compensation during the next 24H (GPS pps not available) with a step of 20°C during the same time. The GPS pps signal is coming back after and the part is locked again. In figure 7, we present the statistics of the holdover time error with the described profile for 40 parts.

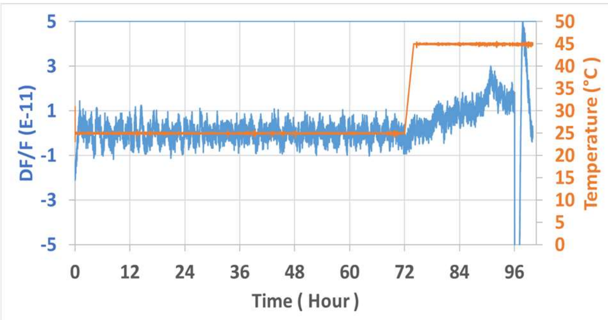

Fig. 6. ROD5242 Holdover performance validation for a thermal variation worst case (rapid variation of temperature 10°C/H between 25°C to 45°C and a plateau at 45°C) on 24H without PPS IN and 48H of learning period.

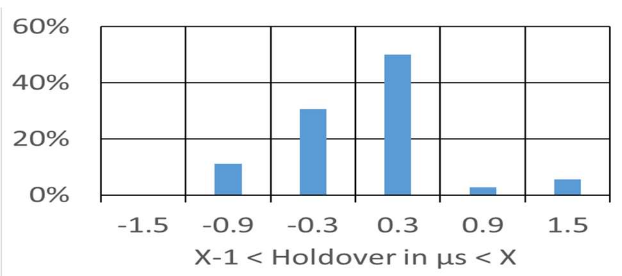

Fig. 7. ROD5242 holdover performance repartition on a 40 parts batch for a thermal variation worst case (rapid variation of temperature 10°C/H between 25°C to 45°C and a plateau at 45°C) on 24H without PPS IN and 48H of learning period.

III. Different Possible Scenarios of Holdover

Coming back to the figure 4, we can see there are different scenarios after the holdover period:

1/ when the pps is back and the TIE is lower than 1.5us, the OCXO comes back in the "locked" state (figure 9),

2/ the pps is not coming after 24H of holdover or after half the learning period, the OCXO stays at the final value of the compensation (figure10 at 12H) and go in the "uncompensated" state, it can come back in the free run mode thanks to a "manual" reset through the I2C bus (figure 10 at 24H) or if the TIE is less than 1.5us, it comes back to the "locked" state (figure 10 at 8H),

3/After the holdover period, if the TIE is upper than 1.5us, it automatically comes back in the "free run" state (figure 10 at 24H).

In all the situations, the pps out of the OCXO can be activated or not by the choice of the customer. It can also be activated in NCO mode. The time period of the guaranteed holdover TIE can be estimated between 0 to 24H for different values of TIE between 0 and 1.5us, required by the customer, as shown in figure 8. It is always available in the data base reachable by I2C bus and is provided as the remaining time of guaranteed holdover. For this computation, we use the worst case compensation error.

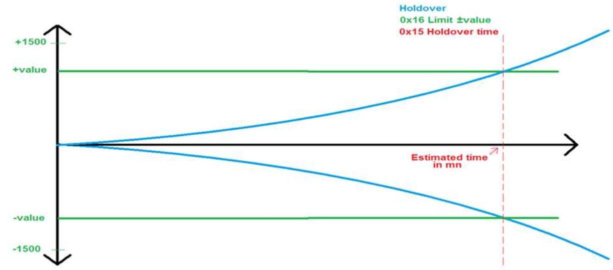

Fig. 8. Fixed Values for the TIE versus holdover time.

IV. Measurement

We have validated the different scenarios by measurement. We will show some of them. The figure 9 shows the nominal scenario 1/, described in the chapter III. The learning time is sufficient to have a TIE lower than 1.5us during the holdover period and a recovery to a TIE less than 50ns in less than 4H after the coming back of the GPS pps. The figure 10 gives a mix of scenarios 2/ and 3/.

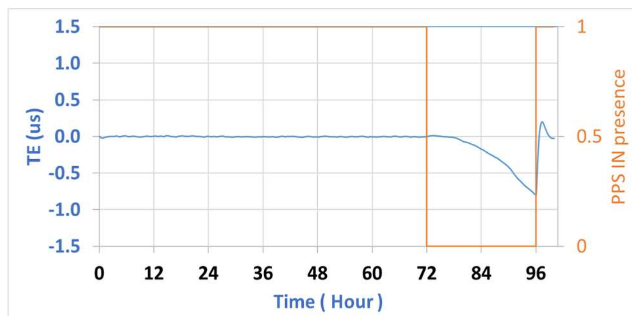

Fig. 9. ROD5242T1 Time error during the holdover for a thermal variation worst case (rapid variation of temperature 10°C/H between 25°C to 45°C and a plateau at 45°C) on 24H without PPS IN and 78H of learning period.

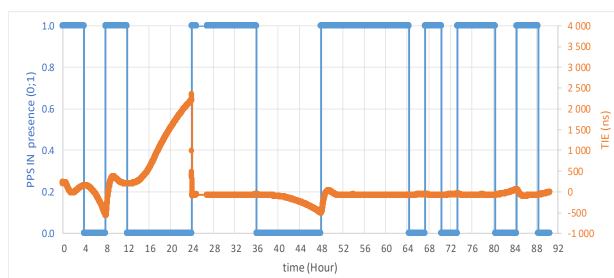

Fig. 10. ROD5242T1 Time error during different scenarios of period of learning (pps in presence =1) and holdover (pps in presence =0) where the learning period is lower than 2 time of the holdover period before the first 48H. At 64H, there is a cumulated 28h learning time, that permits a guaranteed TIE better than 1.5us during the following holdover periods lower than 14 hours.

V. CONCLUSION

In conclusion, we have developed and described two OCXO platforms to guarantee a TIE less than 1.5us during a 24H period of holdover and improved their behavior over multiple scenarios. They use an ageing learning if a GPS pps signal is available and an ageing compensation during the holdover period. The only difference between the two platforms is their sensitivity to the temperature. We have forecasted and minimized the impact of different scenarios of events which can happen during the life of the product. We have discussed of the different options based on customer feedback. Customer can now adjust their platform to match for different conditions of their usage.

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[2] L. Schneller, P. Canzian, V. Candelier, S. Galliou, G. Cibiel "New state of the art of thermal sensitivity with Space Ultra Stable Quartz Crystal Oscillator", EFTF 2010.