



Introduction

The evolution of 5G begins with the introduction of new radios supporting new spectral frequencies. LTE-U, LAA, MulteFire and LWA technologies increase the throughput to the UEs significantly. Small Cells are evolving to support multi-bands and multiple radio technologies. Advanced HetNet features such as CoMP and eICIC are also critical for state of the art Small Cells. Combined with carrier aggregation, these features drive enhanced synchronisation requirements with frequency and phase support. High quality synchronisation is critical for the operation of Small Cells over various operating conditions and over the operating lifetime of the equipment. While the technical requirements for Small Cells – the miniature mobile base station – remain identical to that of a macro base station, the cost structure of Small Cell equipment must be highly competitive.

Best for Service Providers and Consumers

Rakon's OCXOs and Ultra Stable TCXOs meet the frequency and timing requirements of Small Cell designers. Rakon oscillators independently maintain time and frequency accuracy for extended periods, providing better service availability at the network edge. Many Small Cell designs leverage Power over Ethernet (PoE) technology for the system's power supply; low power (20 mW) TCXOs contribute little to the overall power budget and are widely used.

Pluto+™ Ultra Stable TCXO

Rakon's world class TCXOs are powered by in-house developed Pluto+™ technology, providing tight temperature stability (± 50 – 100 ppb) enabling excellent frequency holdover. The very low phase noise performance (20 MHz, -130 dBc/Hz @100 Hz) ensures higher Quadrature Amplitude Modulation (QAM) rates with very little contribution to the Error Vector Magnitude (EVM). Rakon's integrated dual output solution based on Pluto+2™, eases the synchronisation design flow in Small Cell solutions addressing multiple bands like CBRS. Rakon's advanced manufacturing facility uses high resolution temperature testing to screen crystals for activity dips. These test systems help produce TCXOs with excellent temperature sensitivity (as low as 10 ppb/°C) which is key in low loop bandwidth packet-based synchronisation applications like NTP and PTP.

Unique TCXO Advantage

– Guaranteed Life Time Operation

A key differentiator of Rakon's TCXOs is their patented tilt compensation technology. This keeps the TCXOs within frequency stability specification, regardless of voltage control adjustments which are required for ageing compensation, and thus long term operation of the equipment is guaranteed. The superior performance of Rakon's Pluto+™ based products enables development of the best price/performance, timing and synchronisation solutions for Small Cells.

◆ Why Rakon for Small Cells?

For the system designer, Rakon's oscillators offer ease of integration and guaranteed consistency in performance, through:

- Superior FvT, ageing, slope and phase noise performances.
- Guaranteed performance for the life of the equipment.
- High resolution testing in manufacture ensuring tight control of parameters.
- Low power, profile and FIT rates.
- Predictable, linear tuning range.



SMALL CELL FORUM

Neptune™ 50 ppb TCXO

Rakon's Neptune™ family TCXOs, with leading edge ASIC technology and low ageing / low hysteresis crystal technology provides the industry's best in class temperature stability (50 ppb across -40 to 85°C) TCXOs, at lowest power (30 mW) and profile (5 x 3.2 mm). With superior ageing performance (10 ppb/day) and high resistance to airflow, Neptune™ TCXOs are ideal candidates for packet based synchronisation references, for which the temperature sensitivity is critical. The ability to extend its operational range to 105°C enables Neptune™ TCXOs to be deployed at outdoor radio platforms. Analogue compensation techniques enable Neptune™ TCXOs to have low phase noise and low subharmonic levels which are suited for radio applications at high QAM rates.

Mercury+™ IC OXCO

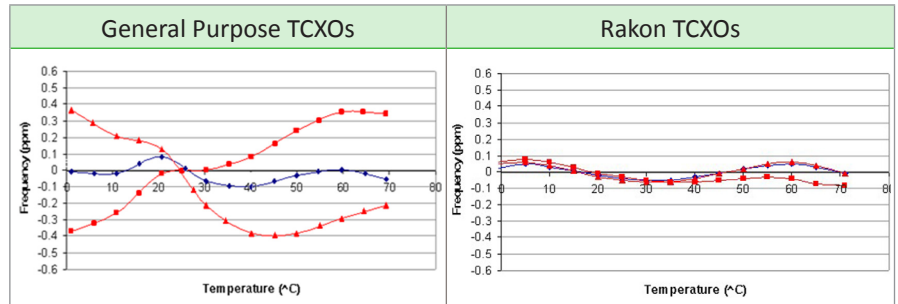
Applications requiring short to medium term holdover and very low temperature sensitivity use OXCOs as synchronisation references. Rakon's Mercury™ and Mercury+™ technologies have made possible, the smallest (14 x 9, 9 x 7 and 7 x 5 mm), lowest power consuming (300 mW) and most reliable (FIT of 30) OXCOs in the industry, with temperature stabilities between ± 5 to ± 50 ppb. The LTE-A and LTE-TDD Small Cell technologies require tight phase accuracies (1.5 μ s) and applications like location-based services are driving the accuracy requirements to even more stringent values (~ 500 ns).





Impact of Linearisation on Small Cell Designs

Rakon's TCXOs are fitted with a patented 3rd order compensation polynomial which will pre-distort the control signal to maintain the linearity across all control voltages and temperatures. As time goes by, the oscillator ages, forcing the control voltage to move from nominal to the edges. As shown in the figure on the right-hand side, generic TCXOs go out of temperature stability specification over time, causing the equipment to fail. Rakon's TCXOs perform within specifications at extremes of the voltage control and across the temperature range. This is a key differentiator between Rakon TCXOs and general purpose TCXOs.



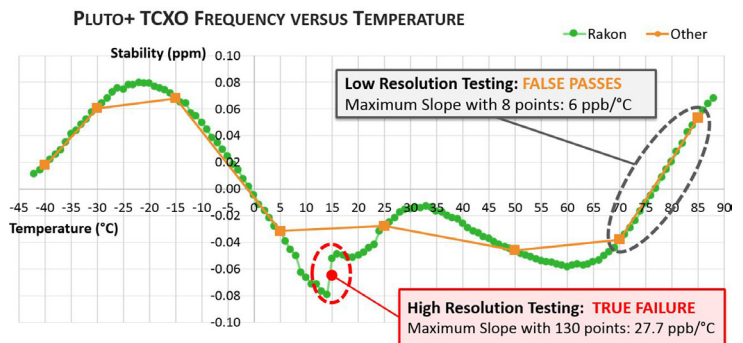
High Resolution Frequency stability Over Temperature Testing to Avoid Activity Dip

Rakon employs fine resolution temperature testing to identify and screen out any oscillators that display activity dips. Activity dips are unwanted sharp variations in crystal resonator behaviour. These could be as a result of non-optimised crystal or blank design and manufacturing processes. Rakon designs, manufactures and maintains its own in-house designed test chambers for its oscillators. With a long history of testing millions of consumer grade TCXO devices per week, Rakon has the experience and expertise needed to mass produce higher end, ultra stable devices for the Small Cell market.

For example:

A TCXO with Frequency slope $(\Delta F/\Delta T)^* = \pm 20 \text{ ppb}/^\circ\text{C}$.
 $\Delta F/\Delta T^*$: ΔF – Frequency drift (ppm/s), ΔT – Temperature change ($^\circ\text{C}/\text{s}$).

- > **Low resolution testing: FALSE PASS**
8 point testing passes the unit, as it is only able to detect the maximum slope of **6 ppb/ $^\circ\text{C}$** .
- > **High resolution testing: TRUE REJECT**
Rakon's 130 point high resolution testing finds any sudden frequency jumps, and detects the worst slope of **27.7 ppb/ $^\circ\text{C}$** .



Rakon Oscillators for Small Cells

Rakon offers the broadest range of oscillators optimised for the Small Cell market. As an early member of the Small Cell Forum, Rakon has been an integral part of the Small Cell ecosystem, helping enable the synchronisation technology for Small Cells. With a full range of TCXOs and OCXOs, Rakon is able to provide synchronisation solutions for a wide range of customer requirements. The following table summarises the solutions offered by Rakon:

Oscillators	TCXOs					OCXOs		
	Pluto+™ (5x3, 7x5)	Pluto+2™ Dual output (7x5)	Neptune™ (5x3, 7x5)	Mercury+™ (9x7, 7x5)	Mercury+™ (14x9)	Mercury+™ Hybrid (25x22)	ROX S4 (25x22, 25x25)	ROX S3 (25x22)
Temp. Stability*	±100 ppb	±100 ppb	±50 ppb	±10 ppb	±5 ppb	±5 ppb	±5 ppb	±1 ppb
Ageing	< ±20 ppb/day	< ±20 ppb/day	< ±10 ppb/day	< ±1 ppb/day	< ±1 ppb/day	< ±0.5 ppb/day	< ±0.5 ppb/day	< ±0.3 ppb/day
Sensitivity	20 ppb/ $^\circ\text{C}$	20 ppb/ $^\circ\text{C}$	10 ppb/ $^\circ\text{C}$	0.5 ppb/ $^\circ\text{C}$	0.5 ppb/ $^\circ\text{C}$	0.2 ppb/ $^\circ\text{C}$	0.2 ppb/ $^\circ\text{C}$	0.1 ppb/ $^\circ\text{C}$
Phase Holdover (1.5 μs)	–	–	–	15 minutes	0.5 – 2 hours	1 – 4 hours	1 – 4 hours	2 – 8 hours
Power (Steady state)	0.035 W	0.035 W	0.03 W	0.4 W	0.4 W	0.5 W	0.75 W	0.75 W

* Temperature range: -40 to 85 $^\circ\text{C}$. 95 $^\circ\text{C}$ and 105 $^\circ\text{C}$ options available on request.

