Enhanced local oscillator for the Event Horizon Imager

Volodymyr Kudriashov, Manuel Martin-Neira

D/TEC, ESTEC/ESA, Noordwijk, South Holland/The Netherlands

Email: Volodymyr.KUDRIASHOV@ext.esa.int

Imaging black holes from space requires a 0.5 mm observation band [1] challenging the "clocks" driving the imager interferometer [2]. A topical ESA-patent [3] offers a prominent candidate solution. We are breadboarding and testing to evaluate an attainable performance.

We proved the solution in [4] by breadboarding the simplest architecture. The frequency stability satisfies the interferometer requirement with an order of magnitude margin, and this obtained stability is compliant with both a temperature difference (±3°C between branches for 4.5 hours, the orbit period) and an inter-satellite link delay (0.2 s in the worst case over the mission).

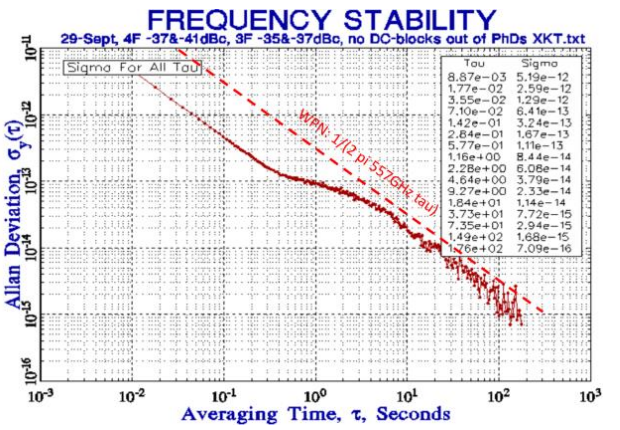

Fig. 1: Allan Deviation between two derived oscillators. Core oscillators are free running, their frequencies are same to a fraction of 1 Hz (higher difference improves the coherence though).

Operation at rather small frequency offsets (up to 2.7 kHz) between core (free running) oscillators would allow to naturally equalize the Doppler shifts over the Inter-Satellite Links, alleviating the need to correct for this specific Doppler frequency shift at the interferometer correlator. This mode, being useful at mission-level, is not possible with the above-mentioned breadboard.

We built an optimized breadboard targeting the new capability to operate at the very close core frequencies and we measured the attainable performance [Fig. 1]. This breadboard is compliant with the required Allan Deviation. The compliance is valid within the required offsets covering the ultimate case of the *identical* frequencies of core oscillators. Hence, the capability to deliver the required frequency stability at very small (virtually 0) frequency offsets between core oscillators has been demonstrated. This is a novelty.

Further improvement of the margin could be achieved by reducing unwanted mixing products. Nonetheless, this current breadboard is fully suitable for a follow-on demonstration of the coherence at interferometer level.

We have breadboarded two local oscillators capable to operate the core (free running) oscillators at (nominally) identical frequencies, useful for the EHI imaging interferometer.

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[1] F. Roelofs et al, "Simulations of imaging the event horizon of Sagittarius A* from space", Astronomy & Astrophysics, vol. 625, pp. A124, 2019

[2] V. Kudriashov et. al. "An Event Horizon Imager (EHI) Mission Concept Utilizing Medium Earth Orbit Sub-mm Interferometry", Chin. J. Space Sci., vol. 41, no. 2, pp. 211-233, 2021

[3] M. Martin-Neira et al. "Syntonisation of Signals Between Satellites", WO patent number WO/2023/147885, 2023

[4] V. Kudriashov et al. "Laboratory demonstration of the local oscillator concept for the Event Horizon Imager", Journal of Astronomical Instrumentation, vol. 10, no. 03, pp. 2150010, 2021