Implementation of Coherent Detuning to Suppress Microwave Leakage in Cesium Fountains at NIST

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A potential source of frequency bias in atomic fountains is due to atomic interactions with microwave fields leaking outside of the resonant cavity used for Ramsey interrogation[1,2,3]. We present an implementation of the coherent detuning scheme[3] for the Cesium fountains at NIST using commercial-off-the-shelf components and discuss its performance.

In the coherent detuning approach, a direct digital synthesizer (DDS) changes the microwave frequency during the Ramsey "dark" interval away from resonance. By choosing the magnitude and duration of the detuning, and/or by manipulating the DDS's phase register offset programming, one can ensure the DDS phase differs by exact multiples of 2π during the two Ramsey interactions[3]. In our implementation, a microcontroller (MCU) counter module observes a divided output of the DDS's system clock. When the correct number of clock cycles have elapsed, the MCU updates the DDS's frequency tuning and phase-offset words by use of its profile register, free from software- or interrupt-driven timing. The MCU does not have to be phase locked to the synthesis chain[3]. Other MCU counter channels can act similarly to coherently detune the DDS during other portions of the launch cycle: for example, before and after the Ramsey interrogation phases. Figure 1 illustrates the phase evolution in our system where the DDS output is only "resonant" during two short windows which correspond to the two Ramsey interactions in the fountain cycle.

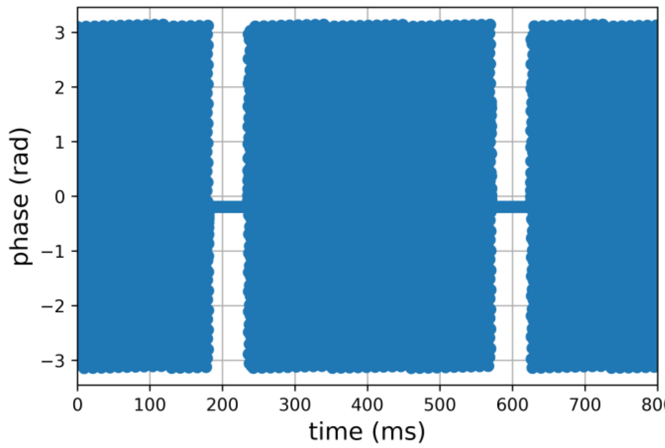

Figure 1 Phase evolution with coherent detuning. The DDS is tuned to resonance for only two time-windows corresponding to the Ramsey interrogation. During the two chosen time-windows, the phase must agree at the level of a few µrad to avoid systematic shifts at the 10^{-16} level[2,3].

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[2] G. Santarelli et al., "Switching atomic fountain clock microwave interrogation signal and high-resolution phase measurements", IEEE Trans. Ultrason., Ferrorelectr., Freq. Control, vol. 56, p. 1319-1326, 2009.

[3] M. Kazda and V. Gerginov, "Suppression of Microwave Leakage Shifts in Fountain Clocks by Frequency Detuning", IEEE Trans. Instrum. Meas., vol. 65, p. 2389-2393, 2016.