High Frequency Piezoelectric MEMS Oscillators

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Low phase noise (PN) frequency sources from 100 MHz to 1.5 GHz rely on mechanical resonators such as quartz crystals and surface acoustic wave devices to form a stable reference. Despite the impressive performance, these components cannot be directly integrated with CMOS electronics, are relatively bulky and are far from attaining the ultimate size, weight and power consumption that would be desirable for high-end commercial, industrial, and especially military applications.

Thin film micro and nanoscale resonators have emerged as a promising class of devices for the synthesis of stable frequency sources. Thin film piezoelectrics have shown to be the only viable transduction mechanism to demonstrate Ultra High Frequency (UHF) references. AlN contour-mode resonators[1] can provide high Q and low motional impedance and are especially suited for the implementation of CMOS-integrable multi-frequency sources on a single chip.

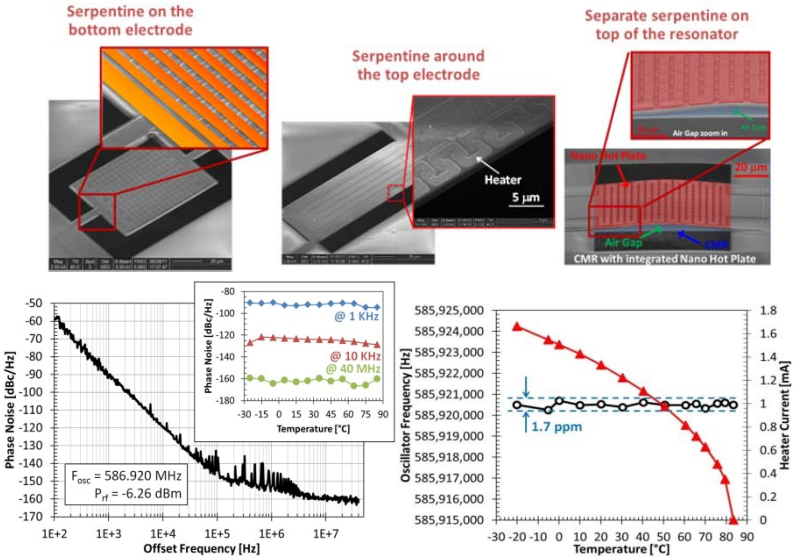

Fig. 1: (top) Three different ways of integrating a serpentine heater with an AlN MEMS resonator: (left to right) heater on the bottom electrode, heater around the perimeter of the resonator, heater suspended on top of the resonator. (bottom-left) Phase noise response of a 586.9 MHz AlN MEMS oscillator. The inset shows the phase noise over temperature at various offset frequencies. (bottom-right) Frequency stability of the ovenized oscillator from - 20 to + 85 ºC and current drawn from a 10 V supply to maintain a stable resonator temperature.

Nonetheless, the ultimate performance of these devices is hindered by their miniaturized dimensions, their complex dynamics and the unknown noise mechanisms associated with it. Here we present the development of high frequency (> 100 MHz) and low phase noise oscillators based on high-Q AlN piezoelectric MEMS resonators. We analytically and experimentally explain how the non-linear dynamics of the AlN resonators are due to self-heating. Furthermore, we measure, for the first time, the residual flicker noise of these resonators in an open-loop configuration, a particularly challenging task at frequencies above 500 MHz, but of paramount importance in order to fully understand the limiting mechanisms of phase noise.

With the aim of delivering temperature stable oscillators, we introduce geometrical variations in the resonator layout to enable low power ovenization (Fig. 1). Preliminary demonstration of a 586.9 MHz oscillator has yielded PN < -93 dBc/Hz and - 160 dBc/Hz at 1 kHz and 10 MHz offsets, temperature stability of 2 ppm from - 20 to + 85 ºC, and acceleration sensitivity < 30 ppb/G.

[1]A. Tazzoli, et al., "A 586 MHZ Microcontroller Compensated MEMS Oscillator based on Ovenized Aluminum Nitride Contour-Mode Resonators" *IEEE International Ultrasonics Symposium*, pp. 1055 – 1058, 2012.