GPS-disciplined MEMS oscillators for amateur radio applications

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The frequency stability of reference oscillators (ROs) is a key performance limiter for all applications that require a timing or frequency reference, including precision sensing, inertial navigation systems, and reconfigurable radio transceivers for amateur radio. ROs based on ultra-high-*Q* micro-electromechanical systems (MEMS) resonators are promising replacements for conventional designs based on quartz crystals due to their compactness, amenability to monolithic integration with CMOS fabrication processes, low cost, and low power consumption. In this presentation, we will demonstrate i) a custom-designed single-chip CMOS sustaining amplifier, and ii) a highly-stable RO based on combining the amplifier with a vacuum-encapsulated breath-mode single-crystal silicon resonator ($Q \approx 10^5$).

The free-running RO has a short-term Allan deviation $\sigma_A(\tau) \approx 1\times10^{-8}$ at relatively small oscillation amplitudes ($P_{osc} \approx -5$ dBm). Further improvements in stability are obtained by increasing the oscillation amplitude such that the resonator becomes significantly nonlinear. In particular, P_{osc} is adjusted in order to operate the resonator near one of its bifurcation points defined by electrostatic spring softening. The conversion of amplitude modulation to phase modulation (AM-to-PM) is greatly reduced near such points, thus reducing phase noise to levels that cannot be obtained using linear resonators. Thus, operation of MEMS resonators beyond the threshold of nonlinearity is promising for improving short- and medium-term RO stability. Moreover, the proposed RO can also be locked to GPS for greatly-improved long-term stability, thus enabling its use as a miniaturized, low-cost, and rugged secondary frequency standard in amateur radio applications.