National Aeronautics and Space Administration

Monolithic W-Band Frequency Synthesizer

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Program: FY22 SURP
Strategic Focus Area: Components and Integrated Systems

Objectives: The objective of this research program has been analysis, design, tape-out, and measurements of low-phase-noise millimeter-wave voltage-controlled oscillators in a commercial foundry SiGe HBT process. Specifically, we study whether an all-electrical fully integrated mm-wave oscillator with extremely low phase noise specification can be realized.

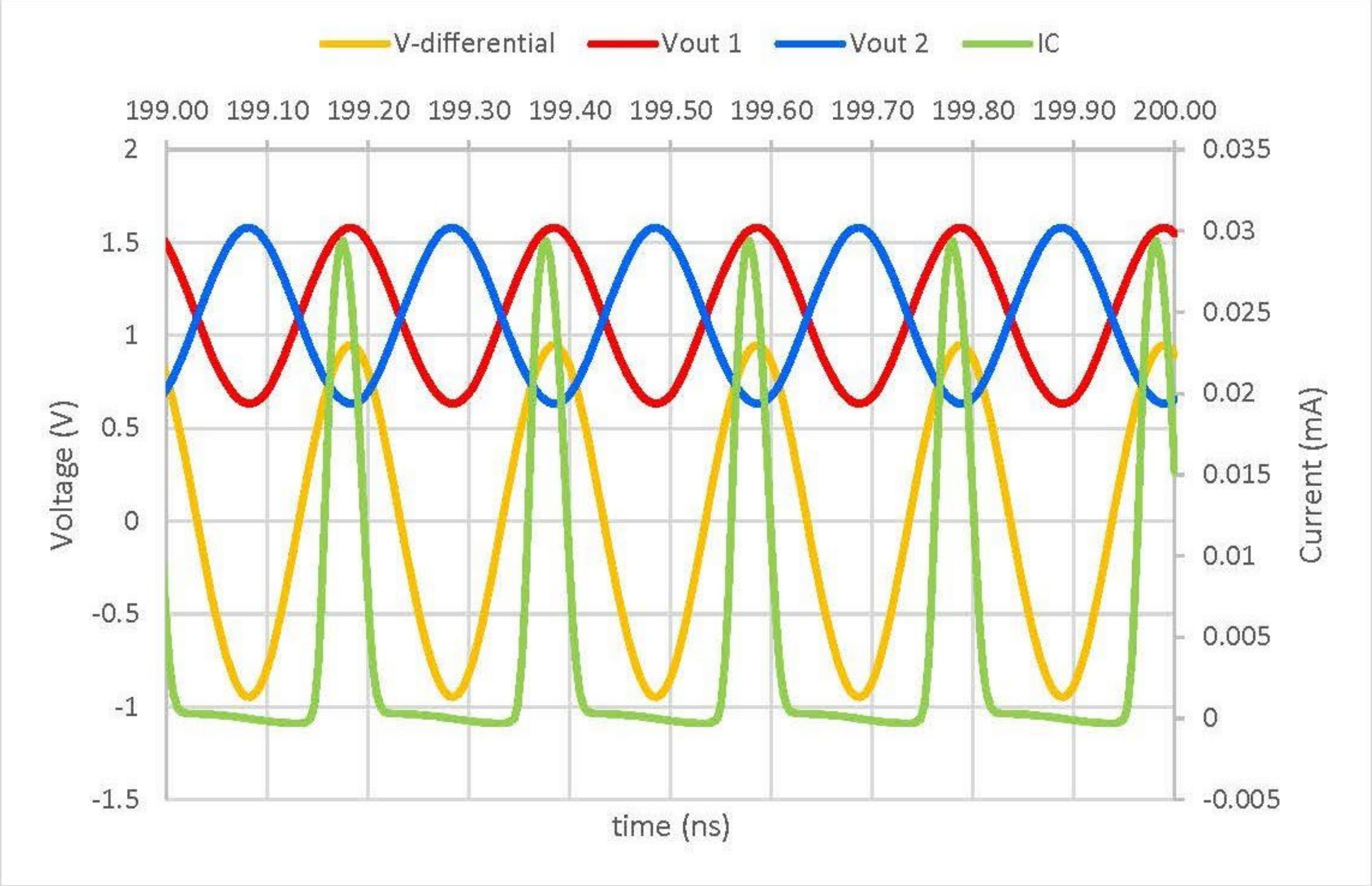
Resonator Type	Typical Quality Factor	Typical Frequency Range
Quartz Crystal	20,000 – 100,000	30 KHz – 200 MHz
Surface Acoustic Wave	1000	30 MHz – 3 GHz
Bulk Acoustic Wave	3000	1 GHz – 20 GHz

Typical resonators performance

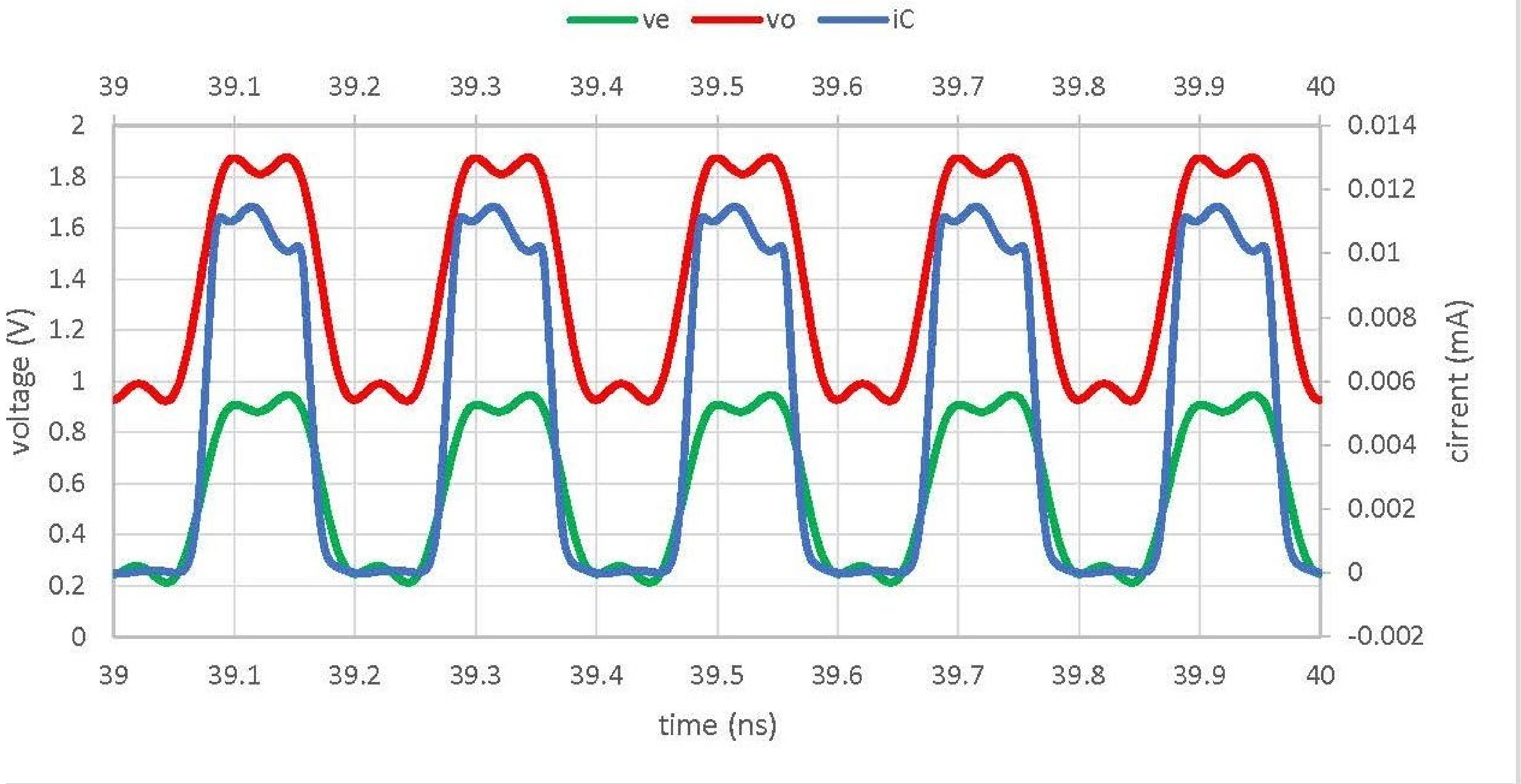
Background: Oscillator phase noise is inversely proportional to the resonator quality factor. At low frequencies, the quality factor of compact mechanical resonators can be quite high.

A standard approach is to multiply the frequency of a low-frequency mechanical-resonator-based oscillator to get to the desired mm-wave frequency. Frequency multiplication degrades the phase noise by the square of the multiplication ratio. For instance, a 100-MHz crystal-resonator-based oscillator, when frequency multiplied by 1000, results in a 100 GHz signal. Frequency multiplication degrades the phase noise by the square of the multiplication ratio (60 dB in this example).

Approach and Results: First, we plan to realize low-phase noise mm-wave voltage-controlled oscillators and optimally designed on-chip resonators**.** Second, we plan to couple any such oscillators on the chip, using a 2D scalable topology, to further reduce the phase noise. To date, we have focused on the analysis and design of Colpitts oscillators using the Tower Semiconductor SBC18 process. To verify the analytical expectations with simulation results without being affected by parasitics, we initially focus on a lower oscillation frequency of 5 GHz. We'll scale the frequency up to around 30 GHz whose third harmonic (already present in a Class-F waveform) will be at the desired 90 GHz frequency range.



Simulated voltage and current waveforms of a conventional differential Colpitts oscillator



Simulated voltage and current waveforms of a Class-F Colpitts oscillator

Significance/Benefits to JPL and NASA: The long-term goal of this collaboration is to develop a compact W-band transceiver for application in radar lander for descent and landing on space bodies, and in space based imaging and remote sensing radars of upcoming missions. The development of this compact radar has several significant building blocks that require innovations in mm-wave circuit design and development to produce a compact system. One of which is a very low phase noise oscillator that results in a high performance LO for RF and a high performance clock for digital subsystems of the radar. Hence resulting in high performance radar that allows optimization of velocity and range ambiguities for radar landers and precise measurements in minuscule fragments of molecules and particles of space and earth atmospheric environment.

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