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Low-phase Noise Sapphire Oscillators with Improved Frequency Stability

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We show that low-phase noise and high-frequency stability can be simultaneously achieved in microwave sapphire oscillators. We describe the 9 GHz sapphire oscillator with interferometric signal processing, which was phase-locked to a stable RF reference by controlling microwave power dissipated in the sapphire resonator. The SSB phase noise of the oscillator was measured to be close to -170 dBc/Hz at Fourier frequency F = 10 kHz [1]. The fractional instability of the oscillator frequency was approximately 2x10^{-13} for integration times from 5 to 50 s.

The use of cryogenic sapphire resonators promises significant improvements in the phase noise performance of microwave oscillators [2]. Yet, serious attention must be paid to the noise mechanisms affecting the cryogenic resonators. The vibrations induced by cryocoolers and power-to-frequency conversion in the sapphire resonator are expected to be the leading causes of the oscillator's excess phase noise. In our recent experiments, we measured the power-to-frequency conversion of the cryogenic sapphire resonator as a function of Fourier frequency. We found that the resonator response to the fast variations of dissipated microwave power is similar to the transfer function of the 1st-order low-pass filter with corner frequency close to the resonator's loaded bandwidth [3]. The measurements were performed with three almost identical resonators cooled to 6 K and excited in the same whispering gallery mode with a resonant frequency near 11.2 GHz. Having measured the cryogenic sapphire resonator's power-to-frequency conversion, we predicted the phase noise spectrum of the cryogenic sapphire oscillator.

References

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