Development of cryogenic sapphire oscillators at HUST

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Cryogenic sapphire oscillator (CSO) can generate microwave signals with ultra-low phase noise. The phase noise of the amplifier in the feedback loop will affect the CSO phase noise through Leeson effect[1]. However, for an oscillator with frequency feedback, we need to consider not only the phase noise of the amplifier, but also the detection noise of the feedback system. It is meaningful for us to develop a noise model to analyze a controlled oscillator to facilitate the improvement of its performance in comparison with a free-running oscillator.

In this study, we consider the detection noise contribution of the feedback loop based on the Leeson's model. We give a phase noise formula which can be used to describe the controlled cryogenic sapphire oscillator. We built two independent CSOs at Huazhong University of Science and Technology (HUST), which can generate 10.8 GHz high-stability microwave signals. By measuring the beat note of the two CSOs we can evaluate their phase noise to be -90 dBc / Hz @ 1 Hz, and the fractional frequency instability is 5E-15@1 s. According to the phase noise model, we are currently limited by the noise of the detection system due to a limited Q factor.

The schematic diagram and results of the CSOs are shown in Fig. 1.

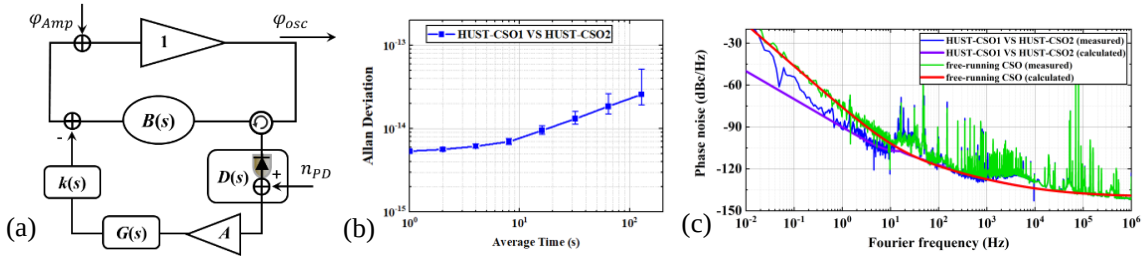

Figure 1. (a) The phase noise transfer block diagram. (b) The Allan deviation of the fractional frequency instability for two CSOs. (c) The phase noise of CSOs.

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[1] D.B. Leeson, "A simple model of feedback oscillator noise spectrum," Proc. IEEE **54**(2), 329–330 (1966).