Development of Phase Lock Loop based on Harmonic Phase Detector

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A novel superconducting element, High-Harmonic Phase Detector (HPD), intended for phase-locking of a Flux Flow Oscillator (FFO) in a superconducting integrated receiver (SIR) has been proposed and experimentally tested. According to our concept a superconductor-insulator-superconductor (SIS) junction is implemented both for down-conversion of the FFO frequency and for phase-locking of the FFO to an external reference by applying the HPD output directly to the FFO control line. The cryogenic HPD can be placed in close vicinity to the oscillator providing extremely large synchronization bandwidth (BW). To realize efficient phase-locking of the FFO the HPD output signal should be maximized by the HPD bias voltage, frequency and power of the local oscillator (LO) and input RF signal. Calculated 3D dependences of the HPD output signal power versus bias voltage and LO power agreed well with experimental measurements.

For demonstration of the HPD operation we used additional SIS-mixer implemented for monitoring of the phase locking effect. Regulation BW of the phase-locking loop (PLL) system based on the HPD as high as 70 MHz has been experimentally achieved; that value several times exceeds BW of any other regular PLL systems used for cryogenic oscillators. Developed HPD system could synchronize up to 92% of the emitted FFO power for free running FFO line as wide as 12 MHz.

In this work we also propose new method for estimation of a synchronization efficiency based on HPD dc signal monitoring. We have developed experimental setup for measuring of the HPD output signal; it was shown that for the HPD operation the Josephson mixing regime is more efficient then quasiparticle resulting in increase of the output signal on 12 dB at moderate noise level raise on 4 dB. Detailed study of the HPD output signal on the SIS junction parameter has been performed in order to optimize the HPD operation.

The HPD PLL system is simple and compact, that is why our concept is very promising for future applications, especially for building of the multi-pixel SIR array and for phase-locking of the THz range FFO.

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