Superconducting Integrated THz Receiver

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***Abstract*—A Superconducting Integrated Receiver (SIR) developed for balloon borne instrument TELIS covers frequency range 450-650 GHz. The DSB noise temperature was measured as low as 120 K. The SIR application for high resolution spectroscopy of breathed out air has been proven.**

I. Introduction

A Superconducting Integrated Receiver (SIR) [1, 2] was proposed more than 10 years ago and has since then been developed for practical applications [3]. A SIR comprises on one chip (size of 4 mm*4 mm*0.5 mm) all elements needed for heterodyne detection: a low-noise SIS mixer with quasioptical antenna, an Flux-Flow Oscillator (FFO) acting as a Local Oscillator (LO) and a second SIS harmonic mixer (HM) for the FFO phase locking. The concept of the SIR looks very attractive for many practical applications due to its compactness and the wide tuning range of the FFO. Presently, the frequency range of most practical heterodyne receivers is limited by the tunability of the local oscillator, typically 10-15% for a solid-state multiplier chain. In the SIR the bandwidth is determined by the SIS mixer tuning structure and the matching circuitry between the SIS and the FFO. A bandwidth up to 30 – 40% can be achieved with a twin-junction SIS mixer design. All components of the SIR microcircuits are fabricated in a high quality Nb-AlN/NbN-Nb tri-layer on a Si substrate. The receiver chip is placed on the flat back surface of the silicon lens, forming an integrated lens-antenna.

II. Application

Light weight and low power consumption combined with nearly quantum limited sensitivity and a wide tuning range of the FFO make SIR a perfect candidate for many practical applications. In particular, the SIR developed for novel balloon borne instrument TELIS (TErahertz and submillimeter LImb Sounder) [4] covers frequency range 450 -650 GHz. As a result of recent receiver's optimization the DSB noise temperature was measured as low as 120 K for the SIR with intermediate frequency band 4 – 8 GHz. The spectroscopic Allan stability time is about 20 seconds; required spectral resolution of about 1 MHz was confirmed by gas cell measurements. Results of comprehensive phase noise measurements will be presented. Several algorithms for remote automatic computer control of the SIR have been developed and tested.

A possibility to implement the SIR for ground-based radio astronomy and future space missions will be discussed. In particular, details of the on-going project directed on development of the SIR for POrtable Submillimeter Telescope (POST), Purple Mountain Observatory, China, will be presented.

Capability of the SIR for high resolution spectroscopy has been successfully proven in a laboratory environment by gas cell measurements. Possibility to use the SIR devices for analysis of the breathed out air at medical survey will be demonstrated. Many of spectral lines very important for such survey and medical analysis are concentrated in the sub-terahertz range and can be detected by such spectrometer. There is also a large niche for applications of integrated spectrometers for the detection of radiation from the newly developed cryogenic Terahertz sources.

A new cryogenic device, an ultra-wideband Cryogenic Phase Locking Loop system (CPLL) for phase locking of a FFO in a SIR will be briefly presented as well. All components of CPLL (including cryogenic phase detector) are resided inside a cryostat at 4.2 K, with the loop length of cables 50 cm and the total loop delay 4.5 ns. Such a small delay results in CPLL synchronization bandwidth as wide as 40 MHz and allows phase-locking of more than 60% of the power emitted by the FFO, even for FFO linewidth about 11 MHz (3 times better that achieved with conventional room-temperature PLL). Such an improvement enables reducing the FFO phase noise and extending the SIR operation range.

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