

## Superconducting Integrated Terahertz Receivers

V.P. Koshelets<sup>1</sup>, A.B. Ermakov<sup>1</sup>, L.V. Filippenko<sup>1</sup>, M.Yu.Fomisky<sup>1</sup>, N.V. Kinev<sup>1</sup>, O.S. Kiselev<sup>1</sup>, A. de Lange<sup>2</sup>, G. De Lange<sup>2</sup>, K.I. Rudakov<sup>1</sup>, M.Yu. Torgashin<sup>1</sup>, V.L. Vaks<sup>3</sup>, J. Yuan<sup>4</sup>, H.B. Wang<sup>4</sup>

<sup>1</sup> Kotel'nikov Institute of Radio Engineering and Electronics of RAS, Moscow, Russia

<sup>2</sup> SRON Netherlands Institute for Space Research, 9700 AV Groningen, the Netherlands

<sup>3</sup> Institute for Physics of Microstructure RAS; Nizhny Novgorod; Russia

<sup>4</sup> National Institute for Materials Science, Tsukuba 3050047, Japan

**A Superconducting Integrated Receiver (SIR) comprises on one chip all elements needed for heterodyne detection. Light weight and low power consumption combined with nearly quantum limited sensitivity and a wide tuning range of the superconducting local oscillator make SIR a perfect candidate for many practical applications.**

### I. INTRODUCTION AND BACKGROUND

A Superconducting Integrated Receiver (SIR) [1] comprises on one chip a low-noise SIS mixer with quasi-optical antenna, an Flux-Flow Oscillator (FFO) acting as a Local Oscillator (LO) and a second SIS harmonic mixer (HM) for the FFO phase locking (see Fig. 1). 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 35% has been achieved with a twin-junction SIS mixer design. All components of the SIR microcircuits are fabricated in a high quality Nb based 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.

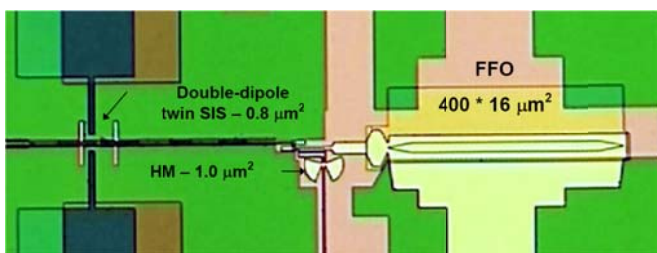


Figure 1. Central part of the SIR chip with antenna, twin SIS-mixer and harmonic mixer for FFO phase locking.

### II. RESULTS

Continuous tuning of the phase-locked local oscillator has been realized at any frequency in the range 300-750 GHz. The output power of the FFO is sufficient to pump the matched SIS mixer in a wide frequency range and can be electronically adjusted. The FFO free-running linewidth has been measured between 0.3 and 5 MHz; resulting in the spectral ratio of the phase-locked FFO above 70% over the range. As a result of

receiver's optimization the DSB noise temperature was measured below 100 K that is about  $4 hf/k_B$ ; the spectral resolution is well below 1 MHz.

All these achievements enabled the development of a 450 - 650 GHz integrated receiver for the atmospheric-research instrument TELIS (TERahertz and submillimeter LIMb Sounder) [2] - the balloon-borne instrument for the detection of spectral emission lines of stratospheric trace gases that have their rotational transitions at THz frequencies. Diurnal cycle of ClO has been observed; the BrO line with a level of only 0.3 K was isolated and clearly detected.

Capability of the SIR for high resolution spectroscopy has been successfully proven also in a laboratory environment by gas cell measurements. The possibility to use SIR devices for the medical analysis of exhaled air has been demonstrated. Many medically relevant gases have spectral lines in the sub-terahertz range and can be detected by a SIR-based spectrometer.

Recently the SIR was successfully implemented for the first spectral measurements of THz radiation emitted from intrinsic Josephson junction stacks (BSCCO mesa) in the frequency range 585 - 735 GHz; linewidth as low as 7 MHz has been recorded in the high bias regime. The phase-locked SIR has been used not only for detection of the BSCCO oscillator emission, but also for the locking of the oscillator under the test. The IF signal down-converted by the SIR is actually a convolution of the BSCCO oscillator signal and stable phase-locked SIR LO. This signal is applied to the PLL, where phase of the signal is compared with phase of the stable reference; the error signal is returned back to the BSCCO oscillator to control its phase. That is the first, but very important step towards development of fully HTc phase-locked local oscillator.

Nowadays the SIR is probably the most functionally complex fully superconducting device that was already successfully implemented for practical applications. In particular the SIR is very attractive for future airborne and space-borne missions as well as for analysis of the breathed out air at medical survey and for security monitoring.

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### REFERENCES

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- [2] Gert de Lange, et al, "Development and Characterization of the SIR Channel of the TELIS Atmospheric Sounder", *Supercond. Sci. Technol.* vol. 23, 045016 (2010).