SIR Chip for TELIS

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We report on first results of development a superconducting integrated receiver (SIR) chip for the 500-650 GHz channel of Terahertz Limb Sounder (TELIS) balloon project [1]. The general concept of the new device is quite similar to that used for superconducting integrated spectrometer presented last year at the Symposium [2]. The device comprises a double-dipole lens-antenna SIS-mixer pumped by an integrated Josephson-type phase-locked flux-flow oscillator (FFO), which provides the rf power also for a PLL harmonic mixer integrated on the same silicon chip of size 4 mm x 4 mm x 0.3 mm. The experimental chips (Fig. 1) are fabricated in IREE, Moscow [3].

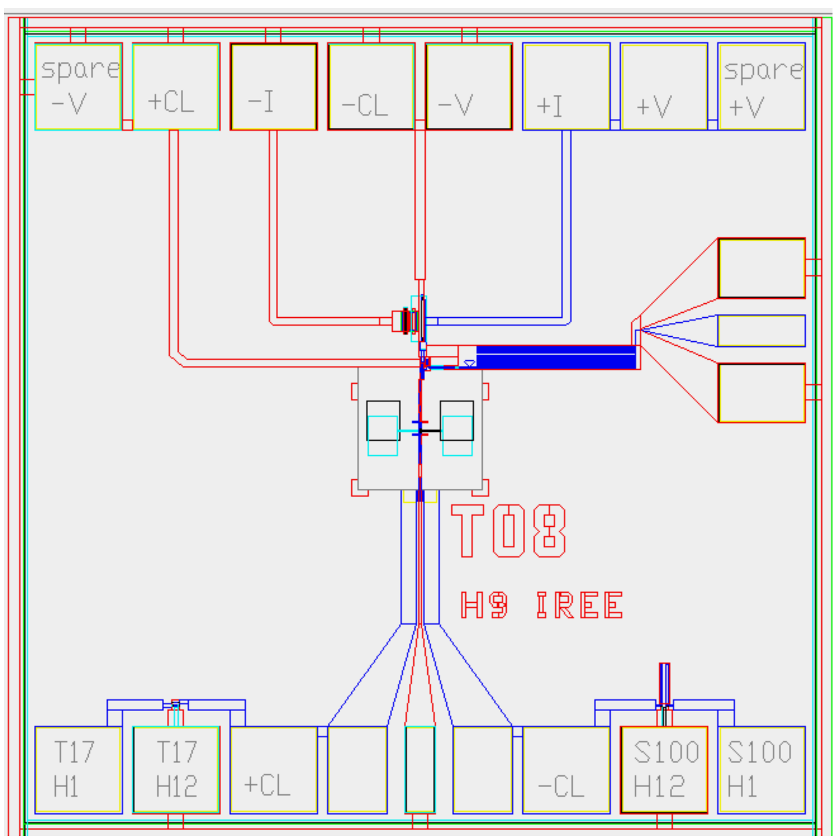

Fig. 1 General chip layout.

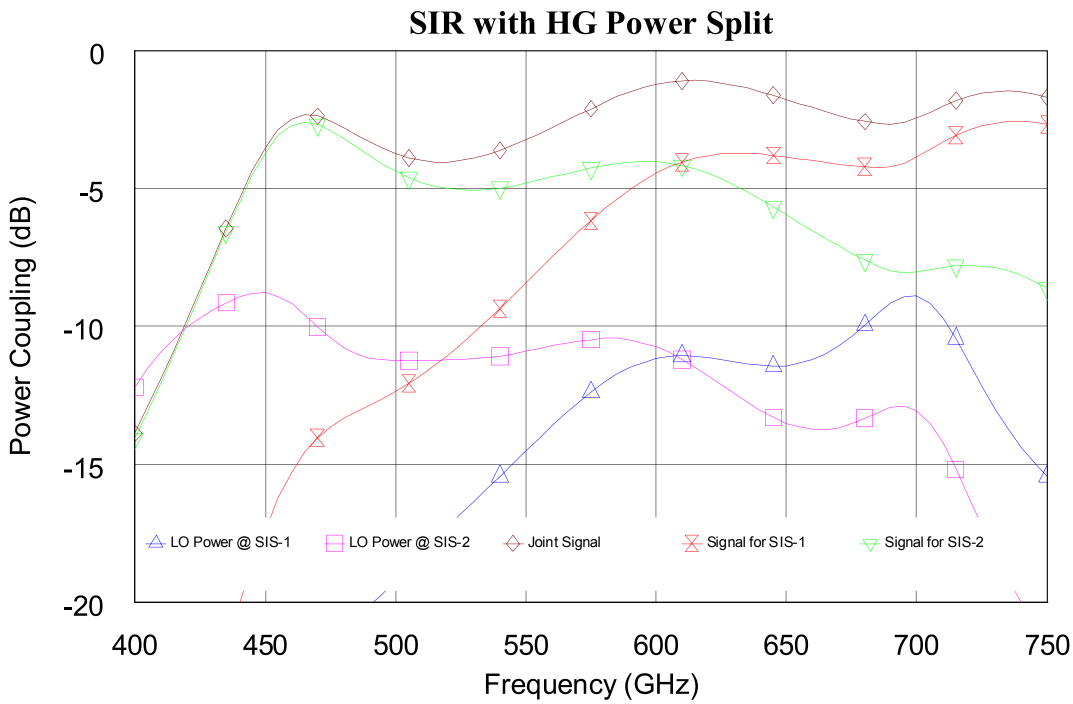

Fig. 2 Power split within the RF circuit of the chip for the case of external harmonic generator. Losses above the gap frequency are not included in the calculation.

A few new solutions are implemented in the SIR chip making it a new generation. To achieve the required instantaneous bandwidth of 500-650 GHz with emphasis on 600-650 GHz frequency range, a side-feed twin-SIS mixer with 0.8 μm^2 junctions is implemented. The improved design of FFO is used suppressing the fine structure resonance phenomenon in the oscillator; the phase-lock/frequency-lock system eliminates industrial noise [4]. To reduce the magnetic field interference to the FFO, a folded control line feeder of the SIS mixer is placed opposite to the FFO, resulting in 10^{-3} suppression coefficient. The “Microwave Office” CAD tool is used for defining the chip characteristics as shown in Fig. 2 and Fig. 5.

A few batches of devices are produced in IREE and preliminary tested in SRON at dc and with a Fourier transform spectrometer (FTS). The FTS test presented in Fig. 3 demonstrates a possibility to obtain the required instantaneous bandwidth for the twin SIS mixer. However, we did not succeed yet in getting wide-band response for the single-SIS mixer as shown in Fig. 4.

The LO pump of both SIS mixer and harmonic mixer, however, is not flat and drops significantly above the boundary voltage of FFO unlike it was designed (Fig. 6). The reason for this behavior is not completely clear yet and has to be studied with the next design modification. We believe this problem can be solved, since SIR with a free-running FFO at 645 GHz has been tested successfully some time ago. A heterodyne experiment is under preparation.

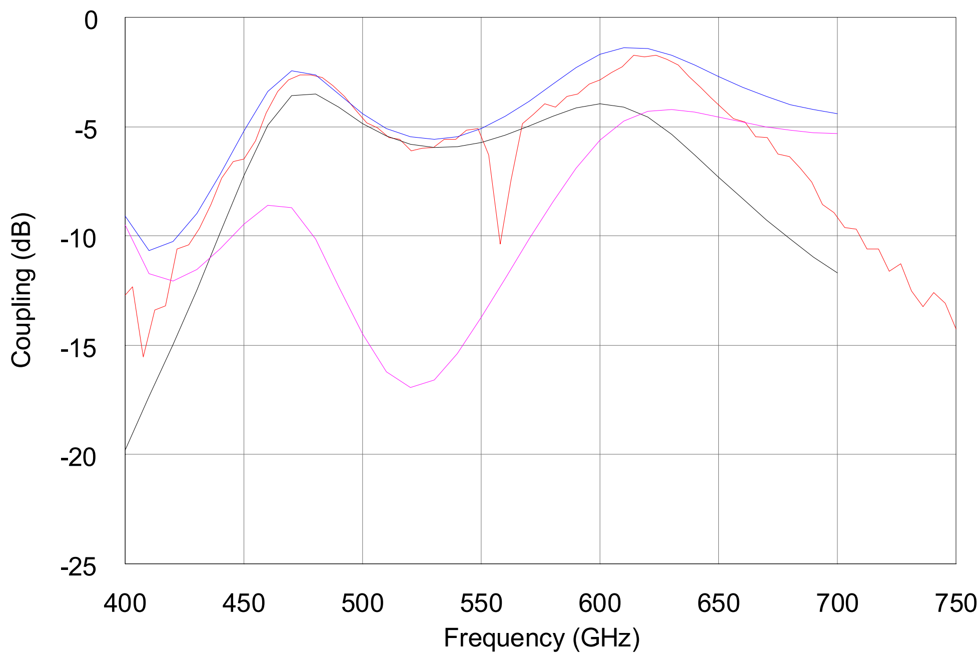

Fig. 3 FTS data (red curve) along with simulated response (smooth curves) calculated for twin-SIS mixer (blue) and for each of two junctions of the mixer (magenta and brown).

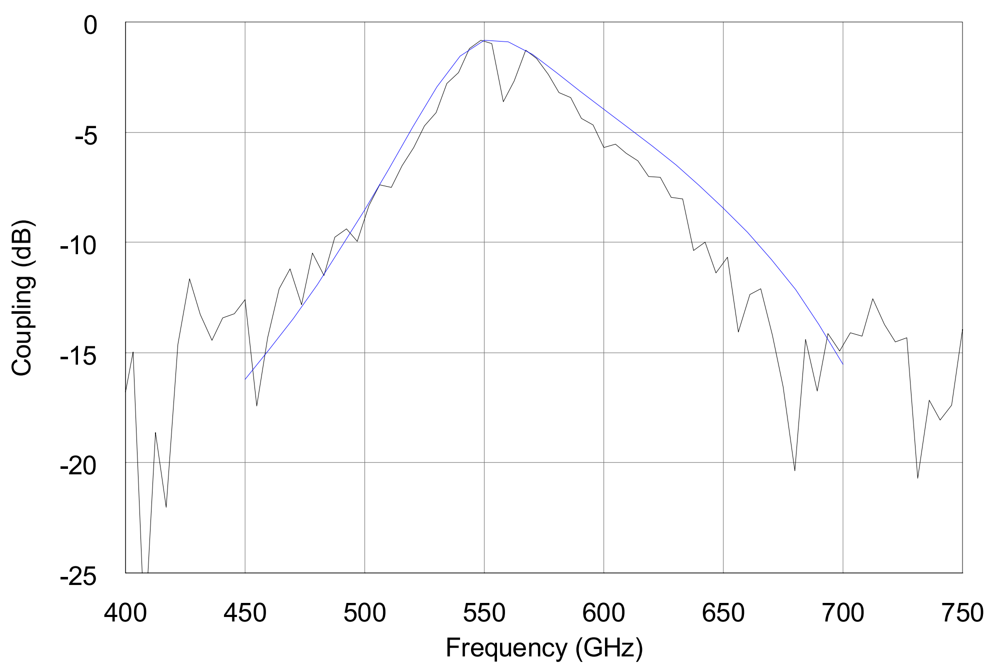

Fig. 4 FTS data (black curve) along with simulated response (smooth curve) calculated for single-SIS mixer (blue).

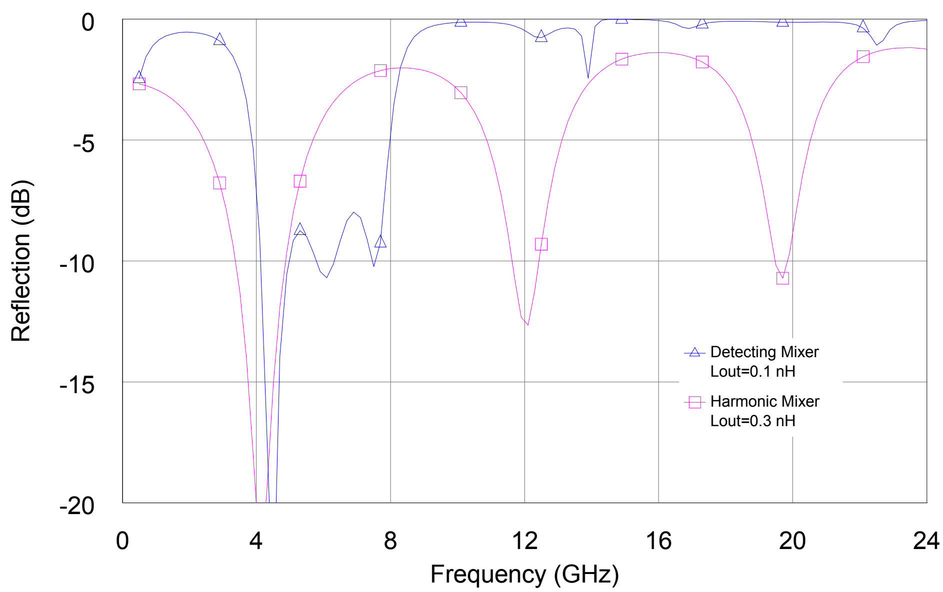

Fig. 5 Estimated IF port reflection for SIS mixer (triangles) and for harmonic mixer (squares) demonstrates 4-8 GHz coupling bandwidth for signal and good match for PLL reference source at 12 and 20 GHz, which is connected via an integrated transformer.

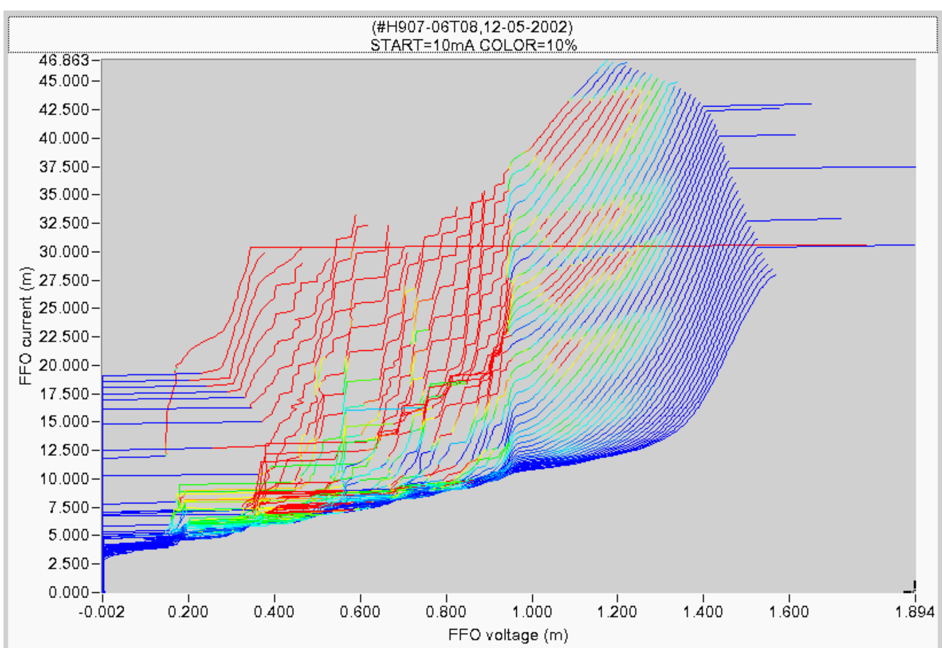

Fig. 6 IV-curves of FFO rainbow-colored by pump level of the SIS mixer. The red color corresponds to the sufficient pump of the SIS mixer; deep blue – no power.

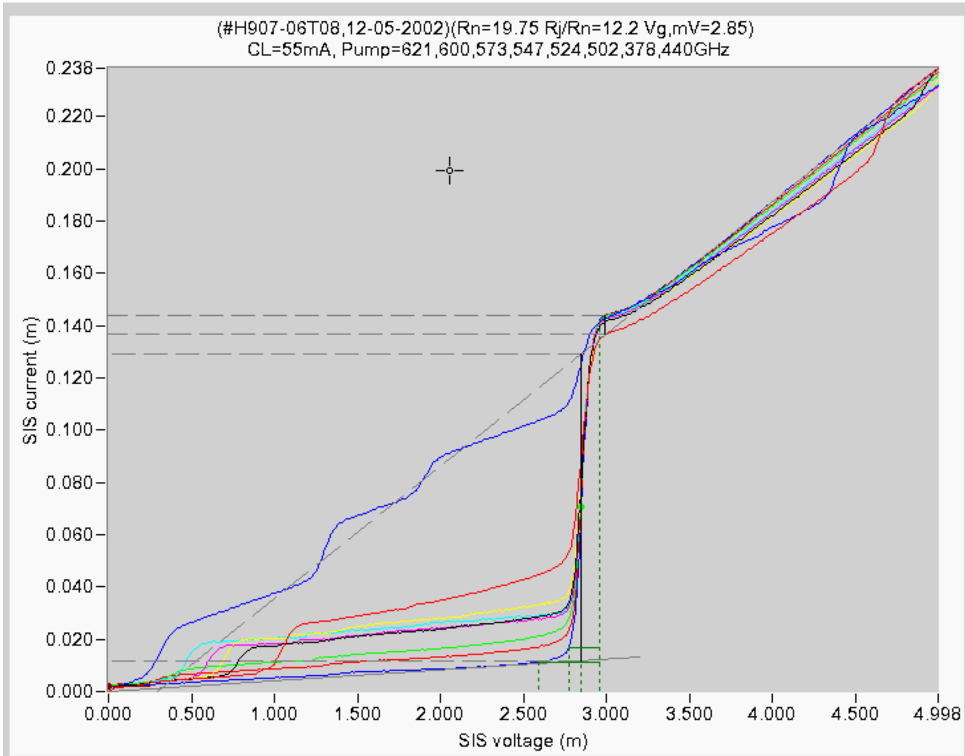

Fig. 7 Twin-SIS mixer pumped by FFO at different frequencies (listed at the top). IV-curves are colored for easier distinguishing.

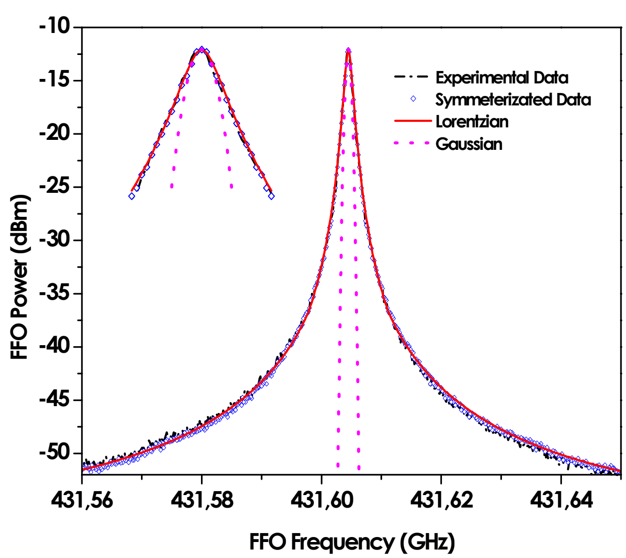

Fig. 8 Oscillation spectrum of the FFO demonstrates Lorencian shape.

Conclusion

Production of chips for TELIS is started satisfactory. Reliable small-junction ($A = 0.8\ \mu m^2$, $R_nA = 25$) SIS mixers are tested to become the main line. Twin SIS mixer is shown to cover entire band 500-650 GHz (and even wider). The FTS response is found repeatable from sample to sample. However, its flatness has yet to be improved via circuit design fine-tuning. The single-junction SIS mixers appeared difficult to tune for the wide-band operation, but they can be used as the low-power (LO) narrow-band option for 600-650 GHz range. The LO power coupled from FFO drops down above the boundary voltage. This effect is not fully understood yet. The linewidth of FFO is found to be of Lorencian shape that means the wide-band noise is dominating and the external interference is negligible.

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