National Aeronautics and Space Administration

A Compact Low-Power Submillimeter Spectrometer

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Program: FY21 SURP **Strategic Focus Area: Visible/IR/submillimeter, in-situ and remote sensing instruments**

Objective: The objective of the proposed work is to realize an ultra-compact, ow power sub millimeter-wave (sub-mmW) spectroscopic receiver using microelectronics technology for lower cost, size, power and high flexibility space missions. One near-term use will be in a CubeSat (APRA) or SmallSat (PIONEER) mission to make an all-sky velocity-resolved survey of J = 2-1 12CO and 13CO spectral line emission. Observing these lines is crucial for understanding the cycling of material between the Galactic plane and the halo, which plays a key role in galaxy evolution. A complete 13CO map of the Milky Way will be invaluable for obtaining the total molecular mass distribution and its relationship to star formation in the Galactic plane. These lines are a foreground contaminant for observing B-mode polarization from inflation in the very early universe and these improved data will provide extremely useful information for the next generation cosmology studies. Another use is in multipixel high spectral resolution imaging systems used with larger telescopes.

Background: Space missions include instruments that add significant weight and volume and consume considerable power, therefore limiting the capability of and contributing significantly to the cost of the entire space mission. Advances in today's Microelectronics technology can provide high-performance integrated instrumentation with a fraction of the size, weight, power consumption and the cost of the traditional approach employing discrete components. The proposed effort is a demonstration of the potential of Microelectronics at extremely high frequencies for space, without any performance degradation compared to the traditional approach. Our proposed implementation promotes the use of integrated instrumentation for economical space missions, especially in the context of the CubeSats and SmallSats.

Approach and Results: Our approach is based on hybrid implementation of the spectrometer receiver to reduce SWaP by an order of magnitude and at the same time to preserve the receiver performance. The full receiver except than the front-end amplifier utilizes microelectronics technology. The receiver can observe two spectral lines at 220.4 GHz and 230.5 GHz simultaneously. The design of the integrated sideband separating down-conversion. After careful study on the existing solutions, the proposed architecture was designed and fully simulated using advanced design software such as Cadence, ADS, Sonnet and EMX. The full superheterodyne sideband separating down-converter was designed and optimized to achieve the lowest conversion loss, noise figure (NF) and at the same time maximize the sideband separation and suppression. The full structure was designed hierarchically with back-and-forth simulation between the advanced circuit solvers and 3D electromagnetic solvers to account for accurate representation of the transmission lines, interconnections and couplings present in the layout. The final design after satisfying all the required design-rules was submitted for fabrication on fastest available silicon technology node from ihp. The down-converted signal can be processed using the previously implemented spectrometer chip at JPL. A sub-hormonic mixer was selected for this design to accommodate for minimum conversion loss, NF and required LO power. Therefore, the LO frequency is reduced to ~half that of the input RF spectral lines. Fig. 1 shows the architecture of the proposed sideband separating receiver down converter, which leverages the weaver image reject topology to perform sideband separation. Fig. 2 shows simulated input return losses and LO power requirement. Fig. 3 shows the full layout of the entire structure that was submitted for chip fabrication. The chip measures 1.5 × 1 mm^2.

Significance: The developed architecture can provide an order of magnitude SWaP reduction. The small size and weight of this solution can facilitate the use of redundant chips as a backup upon any failure resulted from radiation effects and enable large-format focal plane arrays. **Future extension:** An on-chip low noise amplifier (LNA) can reduce the NF of the down-conversion sideband separating receiver and relax the requirement of off-chip InP LNA. The LO synthesizer can be designed and added to the same chip to drastically reduce the power consumption and complexity/weight of the system.

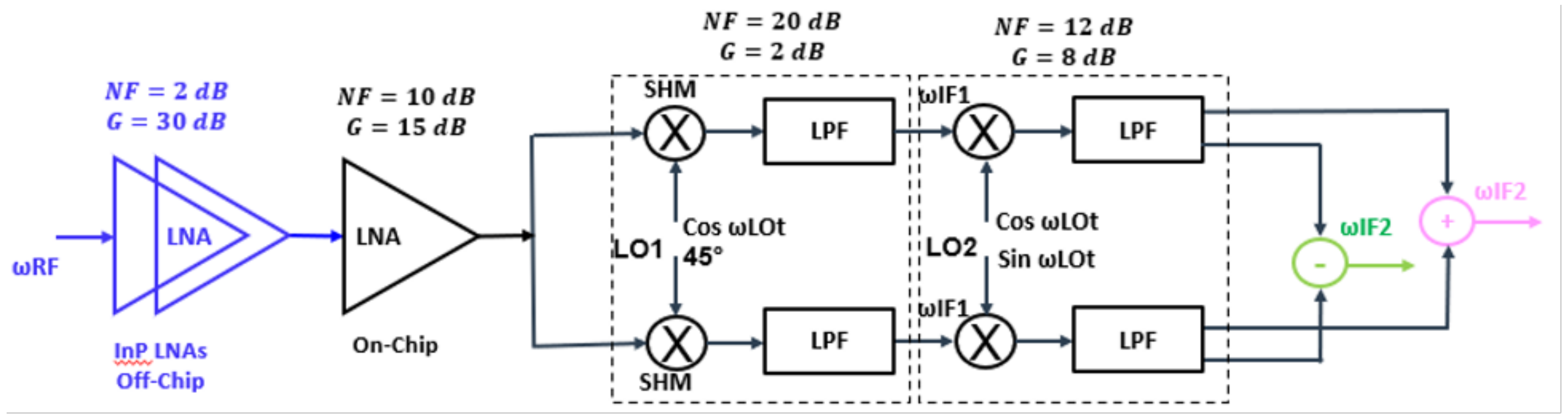

Fig. 1 Block diagram of the proposed sideband separating receiver architecture for simultaneous observation of 220.4 GHz and 230.5 GHz lines of 13CO and 12CO, respectively. Highlighted boxes indicate the current design.

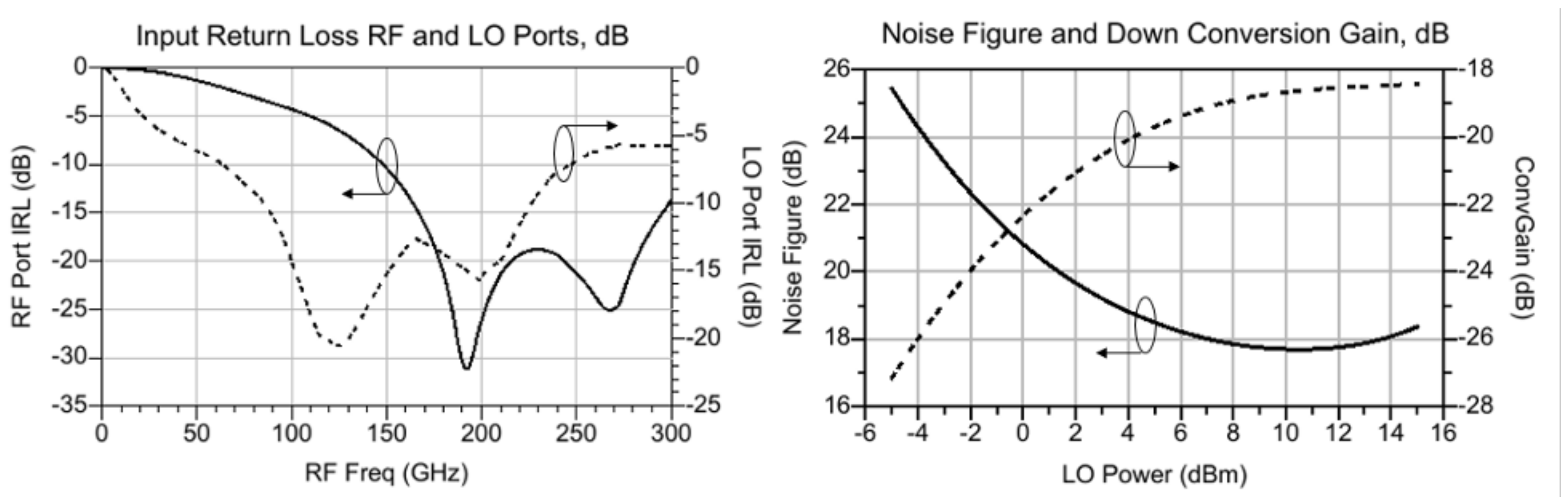

Fig. 2. Simulated performance of the passive sub-harmonic mixer (left) Input Return Loss at RF and LO ports. (right) simulated noise figure and conversion gain versus applied LO power.

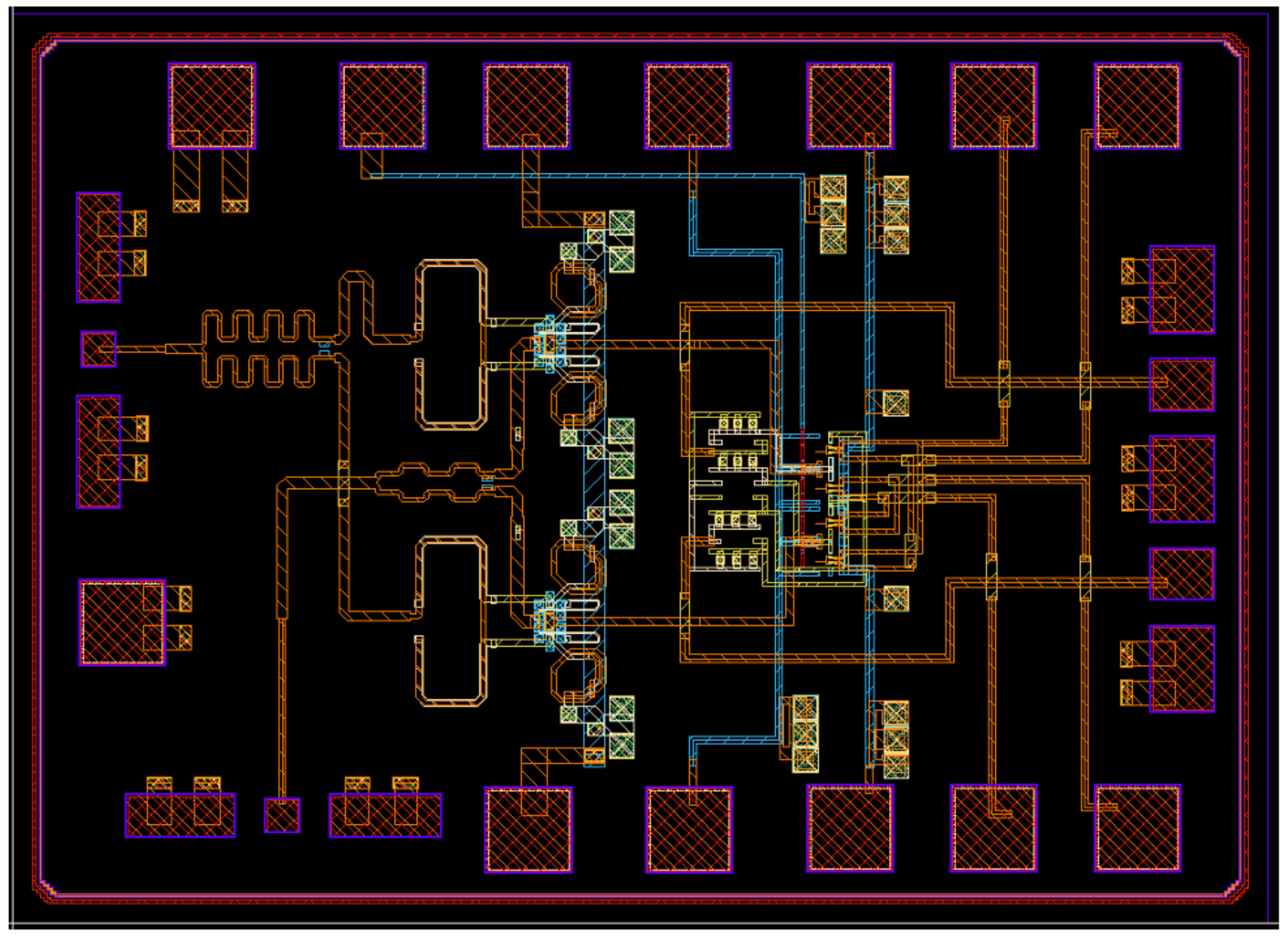

Fig 3. Layout of the designed sub-mmW sideband separating receiver downconverter chip.

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