Slot-Antenna SIS Mixers with Novel Tuning Circuits

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SIS mixers operating at submillimeter wavelengths require tuning elements to compensate for the SIS junction capacitance in order to achieve optimum sensitivity. In particular, on-chip lithographic tuning elements are needed because they can be used either in quasi-optical or in waveguide mixers, and also because their typical broad-band response allows the construction of fixed-tuned mixers which are preferred for aperture-synthesis or focal-plane array instruments. Although such tuning circuits are now gaining acceptance in millimeter-wave SIS mixers, most of the circuits proposed to date do not scale well to the short submillimeter wavelengths. Some circuits become quite narrow-band when scaled to frequencies ≥ 500 GHz, while others become difficult to implement and are subject to large variations due to lithographic registration errors, etc. Our solution to this problem is to use a two-junction configuration, in which the two junctions are separated by an inductor which together with the junction capacitances forms a C-L-C "π"-circuit. This circuit can either be fed from one end only (asymmetrically) or from both ends with equal amplitude but opposite phase excitation (antisymmetrically). Because the inductance is controlled by the separation of the two junctions which are defined simultaneously in the fabrication process, the inductance can be precisely controlled and is nearly immune to lithographic registration errors. Furthermore, the predicted bandwidth of these circuits either approaches (for the asymmetric feed) or matches (for the antisymmetric feed) the bandwidth of an ideal inductively-shunted junction.

These tuning circuits could be used in a broad variety of SIS mixers, including both waveguide and quasi-optical designs. We have designed quasi-optical twin-slot antenna SIS mixers with both asymmetric and antisymmetric two-junction tuning circuits. In the asymmetric case, each slot antenna is coupled to its own two-junction circuit and the two IF outputs are combined; thus a total of four junctions are needed in this mixer. These devices were fabricated using direct-write electron-beam lithography and have been tested over the range 360-580 GHz, and receiver noise temperatures in the range 250-500 K (DSB) were measured. In addition, a receiver using this mixer design was flown aboard the NASA Kuiper Airborne Observatory in order to obtain astronomical observations over the range 490-580 GHz. We are now in the process of fabricating twin-slot mixers with antisymmetric tuning circuits. These devices need only two junctions and can be fabricated using optical lithography, even at frequencies approaching 700 GHz.

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