A 16-ELEMENT SIS-RECEIVER FOR 455 - 495 GHz FOR THE HEINRICH HERTZ TELESCOPE

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Abstract

The development status of the 455 - 495 GHz SIS-receiver array is presented. The array consists of 16 elements arranged in subgroups of 2:4:2. The mixer elements are 1 μm^2 Nb/AlO$_x$/Nb-junctions grown on fused quartz substrates together with the IF-filter and the integrated tuning circuit. The mixers use corrugated feed horns, reduced-height waveguides and a sliding backshort which, in addition to the integrated tuning circuit is required to achieve a broad band response. The junction fabrication technique is summarized. Receiver noise temperatures below 180 K between 430 and 480 GHz have been obtained. The receiver noise does not depend on the frequency at which the backshort is optimized.

Introduction

The need for the efficient use of radiotelescopes has led to the construction of focal plane arrays of receivers at centimeter and, more recently, at millimeter wavelengths [1, 2]. Due to the costs and technological effort at submillimeter wavelengths, telescopes above 300 GHz are currently operating with a maximum of two channels at a given frequency. The 16-element array of 455 - 495 GHz SIS receivers requires particular attention to the design of mixers and SIS-elements. In addition the waveguide mixers must be 22 mm apart between centres, so that all connections (backshorts, IF's, bias and coil currents) must emerge from the rear of the mixers. The separation of the individual elements is limited by the permissable truncation of the lenses preceeding the feed horns.

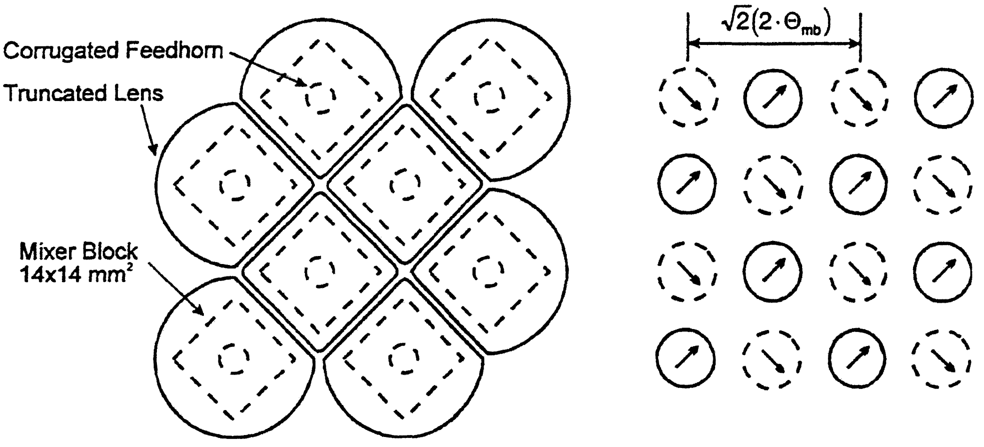

Figure 1: Lens-mixer layout of one subarray (left) and beam patterns of the SIS-array on the sky (right). Circles mark the half-power beamwidth (Θ_{MB} = 16"). Arrows denote beams from the two different interleaved subarrays.

To bring the sky-beams closer together, two interleaving subarrays (of 8 elements each) are employed (Fig. 1), with perpendicular polarisations to one another: for a single array the beams are separated by $2 \cdot \Theta_{MB}$, so that interleaving gives a sky-beam separation $\sqrt{2} \cdot \Theta_{MB}$ for all 16 elements. The lens-horn-mixer units are arranged in a 2:4:2 configuration (Fig. 1). For a facility instrument with so many elements, it is necessary to utilise broad band SIS-structures and to tune each mixer only once in the laboratory: thereafter no further mechanical tuning will be possible.

The noise temperature target for all channels is less than 150 K, including losses due to coupler, window and IR-filters, and IF noise.

Horn and Mixer

Scalar-feeds are used, due to their superior beams and larger bandwidths. The circular horn throat is transformed to a 4:1 reduced-height waveguide with dimensions 480x60 µm. A contacting backshort (BS) is used which will be fixed after initial tuning.

Mixers and feed horns were fabricated by Radiometer Physics, and IF matching-structures (160 to 50Ω for 2 - 4 GHz IF) were designed and constructed in house.

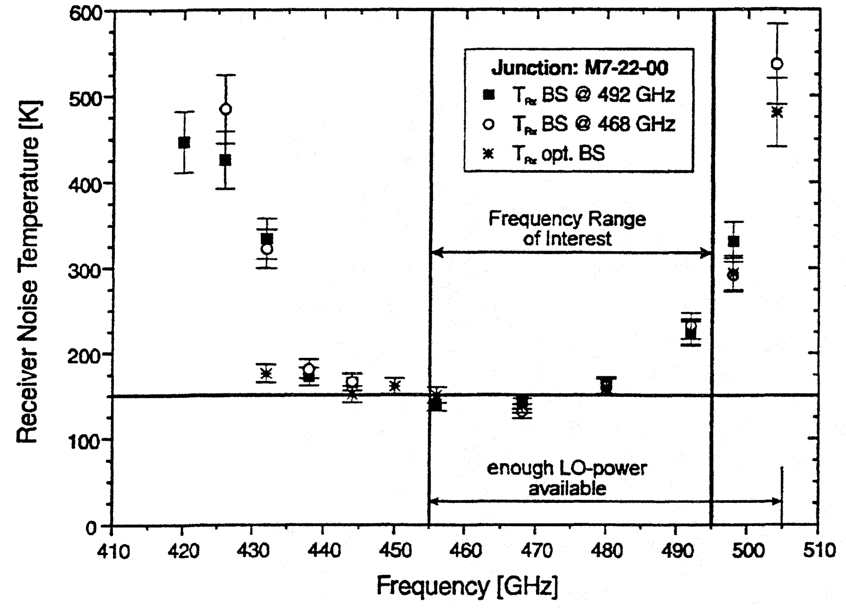

Figure 4: Receiver noise temperature T_{Rx} for a junction with microstrip transformer tuning circuit in the frequency range of our LO. The backshort was optimized at 492 GHz and thereafter kept fixed (closed squares). The open circles denote T_{Rx} vs. frequency for the backshort optimized at 468 GHz and the stars represent T_{Rx} at the optimum backshort position for each frequency.

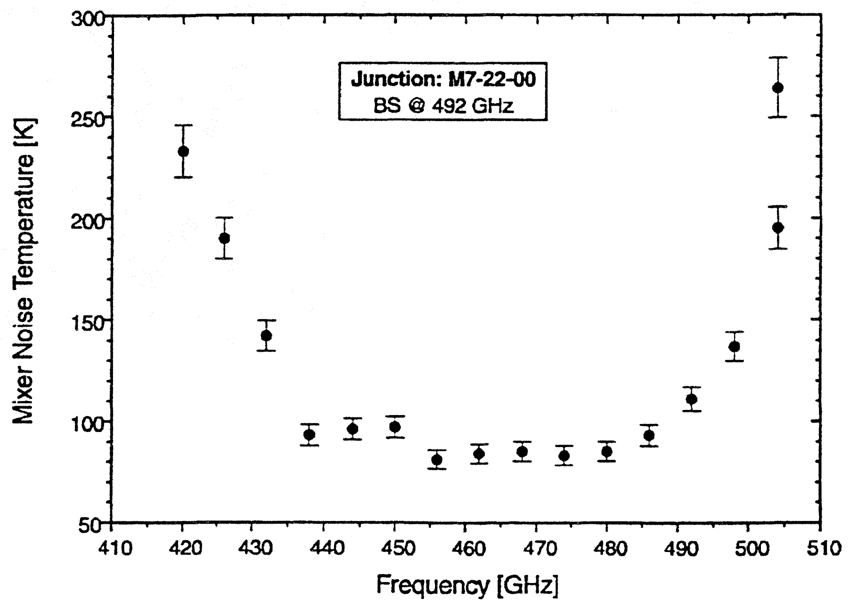

Figure 5: Mixer noise temperature T_M for a junction with microstrip transformer tuning circuit in the frequency range of our LO. The backshort was optimized at 492 GHz and thereafter kept fixed.

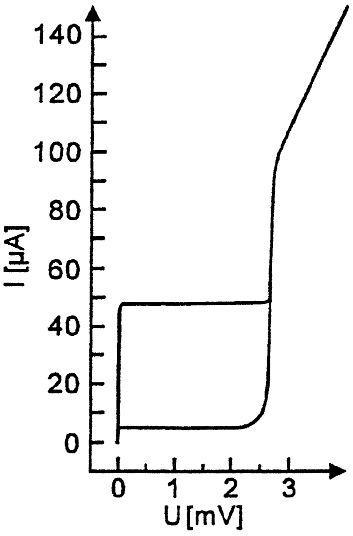

Figure 3: Typical IV-curve of a 1µm^2 junction.

Results

The best receiver noise results were achieved with the integrated microstrip transformer tuning structure [4]. Radial stub tuning circuits were also used, but yielded worse results. The radial stub mixers displayed a negative differential resistance below the gap and therefore no stable operation was possible. The total receiver noise temperature T_{Rx} for a microstrip transformer tuning circuit in the frequency range of our LO is presented in Fig. 4. The BS was optimized at 492 GHz and thereafter kept fixed (closed squares). In Fig. 4 we also show T_{Rx} vs. frequency for the BS optimized at 468 GHz (open circles) and at the optimum BS-position for each frequency (stars). In all three cases the receiver noise temperature in the frequency range 435 - 480 GHz hardly changes within the experimental error (±10 K) and is well below 180 K.

The mixer noise temperature (T_M) was extracted from the measured receiver noise by substracting the IF-noise temperature (T_{IF}) and the losses in coupler, window and filters. T_M is shown in Fig. 5 as function of LO-frequency and varies from 80 to 100 K between 435 and 480 GHz.

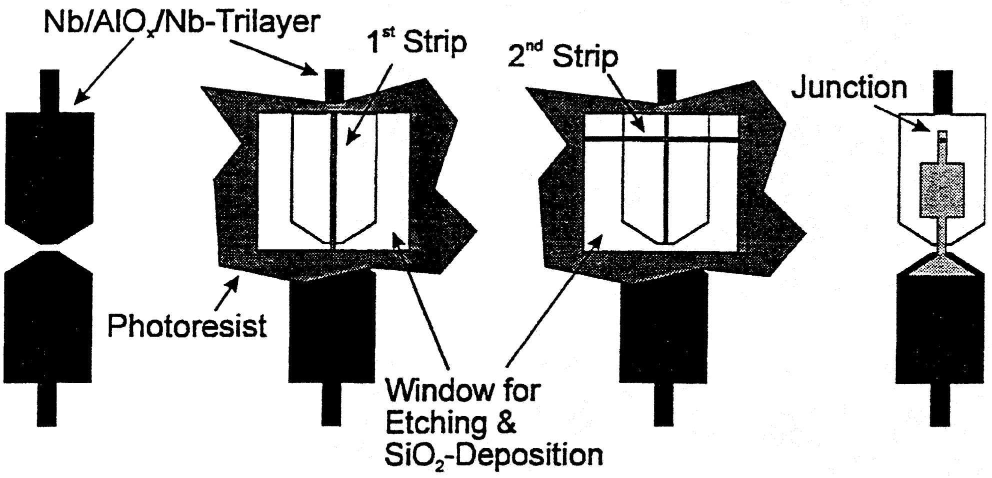

Figure 2: Schematical fabrication of SIS-junctions by means of the SNAP-technique (see text for more details) .

Junction Fabrication

The SIS-junctions were fabricated by means of a slightly modificated SNAP-technique (Selective Niobium Anodization Process) [3] (see Fig. 2). In a first step the Nb/Al/AlO$_x$/Nb-multilayer is deposited in situ into a photoresist stencil. After removing the photoresist by lift-off the antenna structure and the low-pass IF-filter remain on the 200 µm-thick quartz substrate. In the second step a photoresist line is patterned onto the multilayer. The upper Nb-Layer is then removed by RIE followed by anodization, SiO_2-deposition and lift-off. The second production step is the repeated with a photoresist line perpendicular to the first one. In order to optimize the RF match of the junction, a superconductive microstrip circuit is deposited in the fourth production step. The Nb-tuning structure also provides the electrical contact to the upper Nb-layer of the junction, and to the antenna.

We produced junctions of 0.5 μm^2 and 1 μm^2. Typical junction parameters are:

- critical current: 7 - 9 kA/cm^2
- quasiparticle current at 2 mV: 3 - 5 $\mu A/\mu m^2$
- gap parameter: $2\Delta = 2.6$ meV
- normal state resistance: $R_N = 25 - 35\ \Omega$

Fig. 3 shows a typical IV-curve of a 1 μm^2 junction. The relatively low gap parameter is presumably due to the thickness of the upper Nb layer of 30 nm. We tried to keep the upper Nb layer as thin as possible in order to minimize the etching time. This should reduce the underetching of the structure protected by the photoresist and therefore increase the homogeneity of the junction shape.

Conclusions

A 16-element SIS-receiver array is being developed at MPIfR. After the first junction production run at IRAM receiver noise temperatures less then 180 K were achieved over the frequency range 435 - 480 GHz. Based on the evaluation of these first results the calculation of the tuning structure will be optimized in order to improve the broad band RF impedance match of the junctions in the frequency range of interest. The second junction production run is scheduled for April 1995.

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