Noise Performance of ALMA Band10 Receivers Employing High-$j_c$ SIS Mixers

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Abstract—Current ALMA Band10 cartridges covering the frequency range 790 – 950 GHz are equipped with SIS mixers based on standard Nb/AlO$_x$/Nb junctions integrated with NbTiN/SiO$_2$/Al strip lines for the embedding circuit. The current density $j_c$ of the AlO$_x$-barrier type junctions is $10 - 14$ kA/cm$^2$. While the sensitivity performance complies with ALMA receiver noise specifications, tolerance margins are small because of the rather narrow RF bandwidth of the devices [1]. We have fabricated and tested a new set of mixer chips using Nb/AlN$_x$/Nb SIS tri-layers with current density $j_c \sim 30$ kA/cm$^2$ and low leakage. Circuit design is unchanged except for small modifications in the geometry of the matching circuit to accommodate higher-$j_c$ junctions. Compared with junctions in all-Nb SIS circuits, these junctions usually display a lower gap voltage and higher sub-gap leakage, an observation already made with AlO$_x$ type junctions. This is likely because of degraded quality of the tri-layer when grown onto the NbTiN film instead of a blank quartz substrate. The high-$j_c$ mixers under test have a gap voltage of $V_{gap}=2.65$ mV and sub-gap to normal state resistance ratios $q = R_{2mV}/R_n = 16 - 17$ (all-Nb devices: $V_{gap} \sim 2.8$ mV, $q = 20$ or above). For noise performance characterization mixers are mounted into a Band10 cartridge type test set-up. Measured DSB noise temperatures are below 150 K up to 900 GHz and then increase moderately to $T_{rx} = 175$ K at 940 GHz. This fairly flat frequency dependence is a significant improvement over the low-$j_c$ mixers. However, we encountered several difficulties in finding optimum bias conditions for low noise performance and linearity. Depending on the position on the mixer’s power voltage curve, we observe points with gain expansion or gain compression, a phenomena described in [2]. This is directly related to the voltage swing in the IF output power around $V_{pp}/2$ and seems to be more pronounced for mixers based on high-$j_c$ junctions. Details of the measurement method and analysis of the results will be presented at the conference.