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 ~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} ~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 $V_{gap}/2$ 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.

[1] Y. Uzawa, "Development and Testing of Band10 Receivers for the ALMA Project," *Physica C,* vol. 494, 2013
[2] C.E. Tong, "Gain Expansion and Compression of SIS Mixers," *IEEE Transactions on Applied Superconductivity,* vol. 19 (3), 2009