Advanced tuning algorithms for increasing performance of high-frequency SIS mixers

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The NOVA Submillimeter Instrumentation Group at the University of Groningen, The Netherlands, has developed, produced and qualified the full set of 73 operational ALMA Band 9 receivers (600-720 GHz). On all key aspects, these receivers are performing within the performance specifications. Now that all receivers are in place, a potentially easy and very low-cost way to further improve performance may be by pure software-based optimization of certain tuning parameters.

Three tuning parameters are key to SIS performance: SIS bias voltage, LO pumping level and Josephson current suppression (by applying a magnetic field in the plane of the junction). The former two are relatively easy to perform automatically, although there are a couple of pitfalls. The suppression of the Josephson current, however, is much more complicated, especially in the high-current-density AlN-barrier junctions used in Band 9. The individual SIS devices can behave quite differently from each other, and often hysteretic or multiple-regime behavior is observed. In many cases there seem to be unclear tradeoffs between difference performance criteria (noise temperature and tuning stability, for instance). It is clear that in the presence of such effects, stability and repeatability issues are a serious concern. In the tuning parameters that were supplied with the receivers to the ALMA observatory, we always biased ourselves towards the safer and more repeatable regimes, for obvious operational reasons.

In this work, we present early results of the ALMA Band 9 Advanced Tuning study commissioned by ESO. The objective of this study is to investigate more "intelligent" tuning algorithms which should enable the receivers to operate in more critical regimes, which were previously avoided, but with a possibly considerable increase in performance.

In the framework of this study, we first had to develop a new software infrastructure. Our original engineering software [1], while excellently capable of qualifying production receivers (as proven by the successful ALMA Band 9 and Band 5 production campaigns), is not very suitable for adaptive "intelligent" algorithms because of the absence of conditional statements and loop constructions. The new system we developed is structured as a series of extension libraries of the Python language, entirely replacing the functionality of the old engineering code. This gives us the full power of an established high-level programming language suitable for implementation of any adaptive or interactive algorithm we can think of.

Using this infrastructure, as a first step, we have now fully automated the formerly semi-automatic and "eyeball" algorithms, arriving reliably and repeatably at very similar tuning points as with the classical methods. Working from there, we can now investigate incrementally improved and even completely different tuning methods.

As a first important result of these improvements, we found an almost linear relationship between the achievable noise temperatures and the applied magnetic field. This suggests that the focus should maybe not be so much on suppressing the Josephson current itself (as is done traditionally), but on keeping the magnetic field as low as possible while ensuring the stability of the mixer by reliably finding SIS bias voltages just outside the first Josephson feature. This approach has led to a significant increase of the sensitivity in the tested mixers. While the algorithms are primarily intended to interact with the mixers directly, in addition we can perform part of them on our archive data of all delivered ALMA Band 9 mixers. This enables us to give reasonable estimates of the expected performance increase.

References

[1] J. Barkhof, B. D. Jackson, A. M. Baryshev, and R. Hesper, "ALMA Band 9 Cartridge Automated Test System", *Twentieth International Symposium on Space Terahertz Technology*, pp. 246-250, April 2009

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