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A new Cartridge Receiver Channel for the SEPIA Instrument at APEX

Mathias Fredrixon*, Igor Lapkin, Victor Belitsky, Sven-Erik Ferm, Alexey Pavolotsky, Leif Helldner, Denis Meledin, Erik Sundin, Magnus Strandberg, François Joint, and Vincent Desmaris

***Abstract*— In this paper, we present the design of a new cartridge receiver as a prospective upgrade of the SEPIA345 receiver on the APEX telescope. The receiver has all new optical and mechanical layout, featuring extra-wide IF, 4-20 GHz, with new 2SB mixers and OMT-based dual polarization capability covering the 272-376 GHz band. We report here on the performance of the cartridge receiver, closely compliant with the specifications set in the ALMA Wideband Sensitivity upgrade**

***Keywords*— SEPIA receiver, ALMA cartridge receivers, APEX.**

I. Introduction

The SEPIA receiver (Swedish ESO PI Instrument for APEX) [1] was installed at APEX telescope in 2015 and opened up a possibility to observe in a single-dish mode with ALMA Band 5 receiver prototype cartridge. Later, SEPIA was equipped with a prototype receiver cartridge operating in the ALMA Band 9 but equipped with 2SB mixers [2]. In 2020, a third receiver cartridge that covered ALMA Band 7 RF band with 2SB mixers and provided 4-12 GHz IF band, dual-polarization performance via OMT [3] was installed. All three receiver channels were used for routine single-dish observations at APEX while the SEPIA345 receiver was also used for VLBI and the EHT observations. The science requirements for the next generation of receivers for ALMA [4] and ngEHT demand a three- to fourfold increase of the IF bandwidth resulting in a bandwidth close to 4-20 GHz. With this work, we present the design of the ngSEPIA345 (next generation SEPIA345) receiver cartridge that operates in the 272-376 GHz RF band, employs 2SB mixers [5] with extended IF bandwidth 3.5-19.5 GHz, and uses an OMT [6] to provide dual polarization capability. The ngSEPIA345 receiver cartridge is designed to keep full compatibility with ALMA Band 7 cartridge interfaces.

II. The Receiver Cartridge Design

The ngSEPIA345 receiver cartridge uses the standard ALMA receiver cartridge body consisting of 300K flange plate and 110K, 15K and 4K temperature plates separated by fiberglass spacers, see Fig. 1. The cartridge has three independent internal electrical transport chains: LO transport, IF signal transport chain, and DC bias harness. The LO transport chain consists of WR8 vacuum feedthroughs, one for each polarization, and mounted at the 300K plate, stainless steel WR8 waveguides connecting the feedthroughs and the tripplers mounted at the 110K. The straight WR10 waveguides go directly to 4K plate where the adapter WR10-to-WR2.8 connects the LO to the final link made of copper WR2.8 waveguides connected to the mixers' LO inputs. The IF cables are made from two sections, with a split at the 15 K temperature stage, to allow for easier assembly of the cartridge. The DC cabling uses constantan wires and has integrated heat-sinks to control thermal flow. The cartridge optics are the same as in the previous generation of the SEPIA345 cartridge [3] with two offset elliptical mirrors and the corrugated horn though with a modified mechanical layout that accommodates the new OMT-2SB-mixers assembly. The 2SB mixers follow the design presented in [5]. The OMT has built-in twist and configuration with the two outputs on its opposing sides; this allows using two completely identical 2SB mixers. The IF amplifiers [7] are directly connected to the mixer IF outputs as shown in Fig. 1 below.

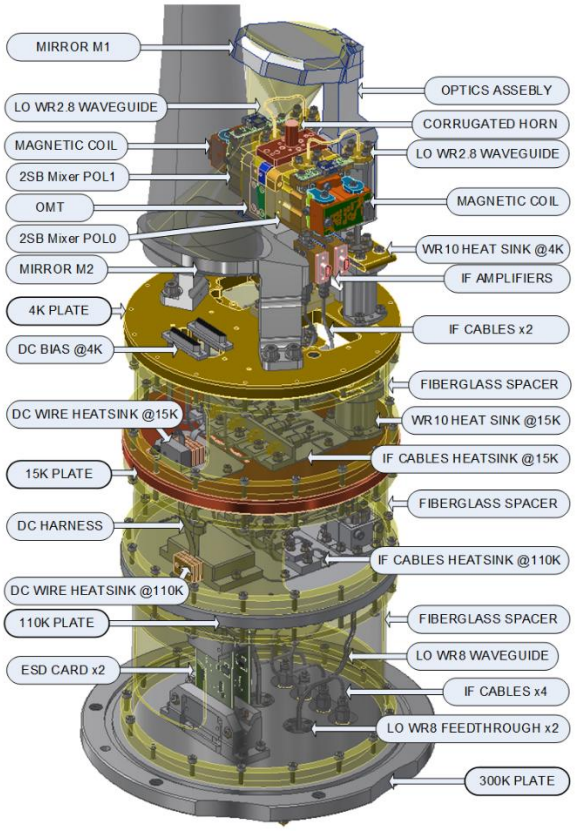

Fig. 1. Annotated the ngSEPIA345 receiver cartridge 3D CAD model. The OMT has built-in twist and its two outputs are placed on opposite sides; this allows using two completely identical 2SB mixers. The simulated RF input beam is shown as dark-grey.

In the design of the ngSEPIA345 receiver cartridge, we largely used experience of designing, constructing, and producing ALMA Band 5 receiver cartridge [8] and ALMA Band 2 receiver cartridge [9], thus vouching for proven design and manufacturing process. During the design process, care was taken to simplify the design as compared to the current SEPIA345 and make manufacturing of mechanical parts simpler, allowing for outsourcing of mechanical work for ngSEPIA345.

With this approach, ngSEPIA345 should be a good candidate for any future upgrade to ALMA B7 WSU.

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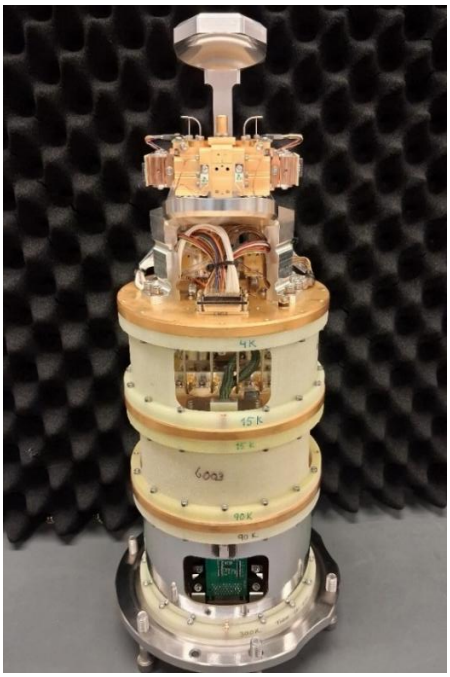

Fig. 3. The ready ngSEPIA345 cold cartridge receiver assembly. The three fiberglass rings were delivered by external supplier, otherwise, most mechanical parts were manufactured by in-house workshops. On the 4K level, the two 2SB mixer assemblies are visible, here mounted on their respective OMT output. Connected from the top, the two WR2.8 LO feed waveguides, allowing for stress relief of the LO transport waveguide chains.

III. Measurements And Results

The fully assembled ngSEPIA345 cold cartridge was characterized [10] in the laboratory before integration into the SEPIA cryostat. The receiver noise temperature was measured using the standard Y-factor method at the cartridge level including the complete cold optics, OMT, 2SB mixer assemblies, cryogenic IF amplifiers, LO distribution chain, and internal IF transport. The measurements were performed over the IF band 3.5 to 19.5 GHz, and over the complete RF tuning range of the receiver, 270-375 GHz.

The measured receiver noise temperature remains below 90 K over the entire RF band and frequency dependence corresponds approximately 4 times quantum noise *hf/k*.

The sideband rejection was measured over the full RF tuning range, and, except for a limited number of isolated points, the measured sideband rejection ratio (SBR) is above 13 dB across the RF and IF bands. A few outliers with SBR below 5 dB could be caused by spurious from the LO leaking into the IF band and could be avoided by choosing a different LO tuning. Since these measurements were obtained without any optimization of the sideband rejection at each LO setting, the result confirms that the ngSEPIA345 receiver provides robust broadband 2SB performance over the full 272—376 GHz tuning range and over the extended IF bandwidth.

IV. Conclusions

Using the experience from previously delivered receivers to the APEX Telescope, work done for the ALMA B5 and B2 receivers, we have designed, built, and tested an updated receiver in the RF band 272 – 376 GHz with 3.5 to 19.5 GHz IF band. ngSEPIA345 will be installed and commissioned during the autumn 2026 at the APEX Telescope in Chile by the GARD team.

V. Acknowledgements

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