A dual-polarization sideband separating Schottky based receiver for ALMA Band 2+3 Warm Cartridge Assembly

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***Abstract*— We present in this paper the development of a dual-polarized sideband separating receiver using semiconductor Schottky and MMIC technology operating at room temperature from 67 GHz to 116 GHz to meet the extended frequency range of ALMA Band 2+3. Preliminary measurements on a single polarization receiver prototype have previously been reported, exhibiting a SSB receiver noise temperature ranging between 3000K and 8000K over the entire 67-116 GHz, and a side band separation between 13dB and 17dB [3]. An upgrade of the side-band separating receiver for dual-polarization is described, featuring a single powerful LO source to pump all four fundamental balanced mixers operating in quadrature mode. Test results including noise figure, gain flatness, sideband ratio, as well as spectral purity are described hereafter.**

I. Introduction

ALMA Band 2+3 receivers development covering the extended frequency range 67-116 GHz is currently on-going in international collaboration coordinated by ESO [1]. This combination of bands is made possible by the continuous technological developments in cryogenic MMIC HEMT low noise amplifiers in order to reach ultra-broadband and ultra-low noise performance, allowing for the relaxation of the constraints in terms of noise temperature on the following stages of the receiver chain. In turns, it enables GaAs semi-conductor technologies such as Schottky diode based mixers and ferrite based waveguide isolator to be used as room temperature operated receiver inside the Warm Cartridge Assembly.

II. Design & Architecture

The Schottky based 2SB receiver presented here is located in the Warm Cartridge Assembly. Each polarization channel of the side-band separating receiver consist of a broadband WR-10 waveguide Y-junction followed by two extended-W band ferrite isolators covering 67-116 GHz, two planar Schottky based fundamental balanced mixers operating in the range 67-116 GHz pumped by a common 75-110 GHz active sextupler and booster W-band amplifier source split and 90° phase shifted via a full-band 3dB waveguide hybrid coupler. IF signals are recombined with an hybrid coupler and amplified.

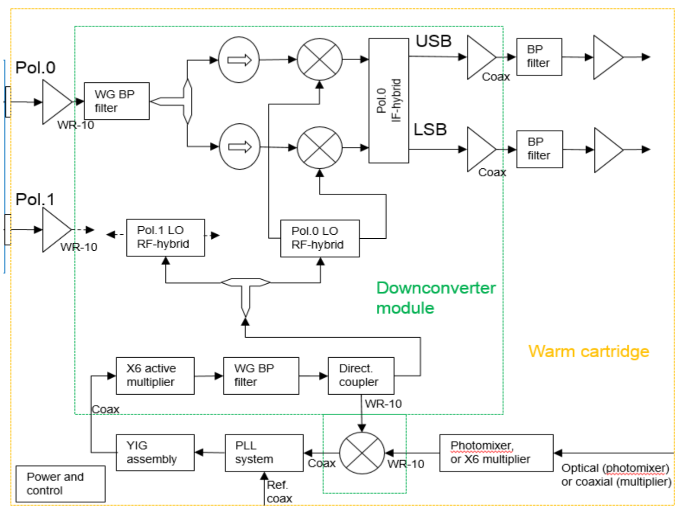


Fig. 1 Schematic diagram of the Warm Cartridge Assembly architecture (orange box), with the 67-116 GHz dual-polarization 2SB receiver (green box) developed by RPG.

III. Component Level Characterization

A fundamental balanced mixer based on cross-bar topology has been designed to cover the extended WR10 waveguide band, from 67 GHz up to 116 GHz. In order to achieve such a broadband RF matching, the use of a ridged waveguide in the RF input waveguide to couple the RF signal to the diodes, as well as the natural mode decoupling of the RF and LO signal is necessary. Measured performance of the 67-116 GHz fundamental balanced mixer are reported in [3], with SSB conversion losses of 7 dB in average over the 67-116 GHz RF range.

Figure 2 shows the measured S-parameters of the RPG 67-116 GHz isolator. The insertion losses are below 1dB up to 100 GHz, and below 2 dB up to 116 GHz. Return losses are <-17dB and the isolation >20dB over the complete 67-116 GHz range.

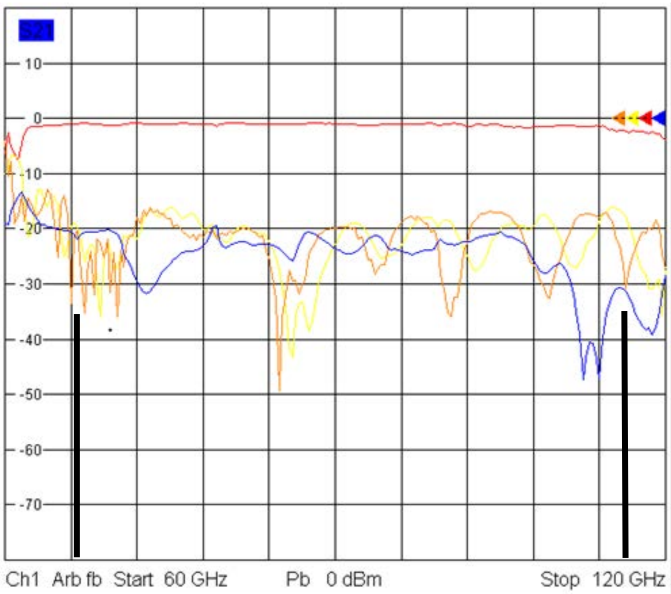


Fig. 2 Measured S-parameters of the extended WR-10 waveguide isolator used in the 2SB receiver. Red: insertion losses, blue: reverse isolation. Orange and yellow: input/output return losses.

A thorough characterization of the LO sextupler source for spurious content has been performed and the results are presented in Figure 3. Following the sextupler, a booster amplifier and a specially designed 79-104 GHz bandpass filter are used to amplify the desired 6th harmonic of the input signal and reject further the out-of-band 4th, 5th, 7th and 8th harmonics of the sextupler. The 5th and 7th harmonics of the fundamental cannot be filtered out as they appear inside the LO band, but exhibit output power levels of -40dBc and -30dBc respectively, in compliance with the ALMA requirements.

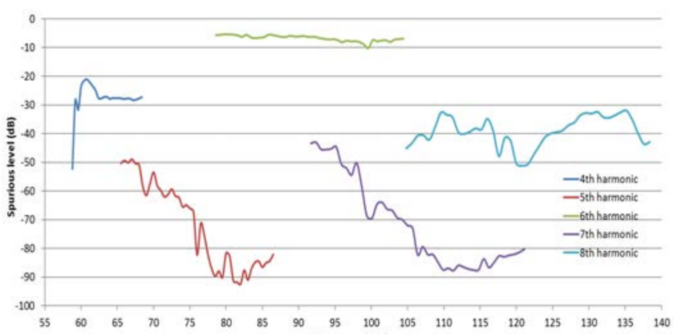


Fig. 3 Measured harmonic content of the sextupler. Top green curve shows the desired 6th harmonic signal. An external filter ensures additional rejection of the 4th and 8th harmonics.

IV. 67-116 GHz 2SB RECEIVER TESTING

A view of the complete 67-116 GHz dual-polarization 2SB receiver is shown in the Fig. 4.Extensive testing has been performed on the 2SB receiver in order to verify the sensitivity of the receiver at room temperature and the gain response. To do so, a traditional Y-factor measurement has been performed using an ambient and LN2 cooled calibration target. The fundamental LO signal is provided externally.

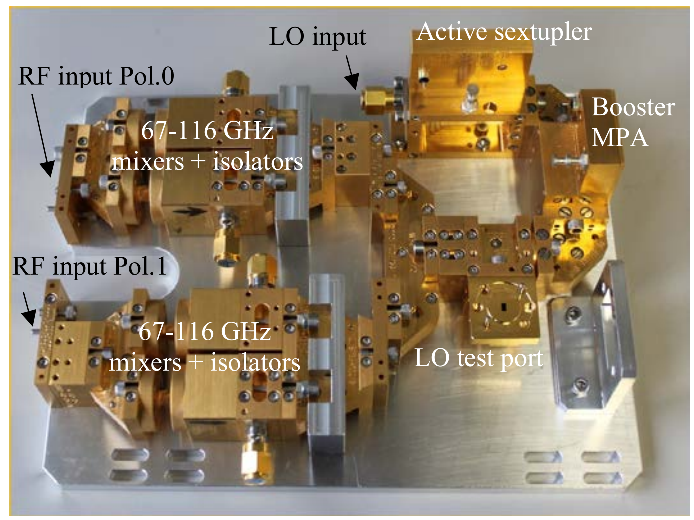
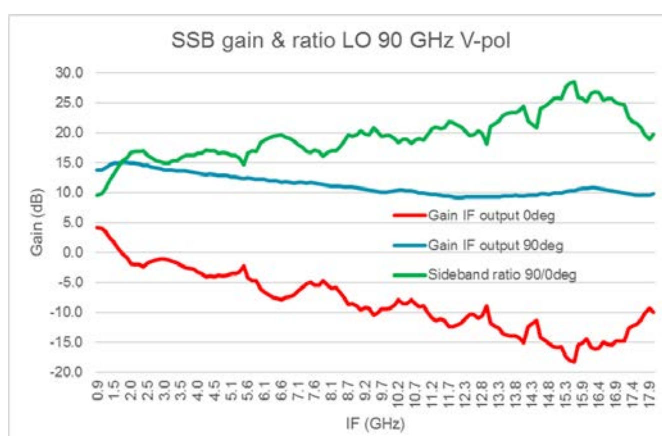


Fig. 4 Photo of the complete dual-polarization 2SB receiver featuring the power LO source, 4x fundamental balanced mixers and isolators, and LO/RF filters.

A. Gain and sideband ratio response

The gain slope and sideband ratio of the complete 2SB receiver has been characterized every 3 GHz over the entire 79-104 GHz LO range, and corresponding RF range 63 GHz to 120 GHz, as the IF hybrid coupler and amplifiers extend up to 16 GHz. Example of test results showing the gain & USB ratio for the V-polarization (top graph) and H-polarization (bottom graph) are presented below. The gain slope (in blue on the graph) is approx. 5dB over 15 GHz bandwidth. The side-band ratio (in green on the graph) is >15dB for the V-polarization, and >10dB for the H-polarization



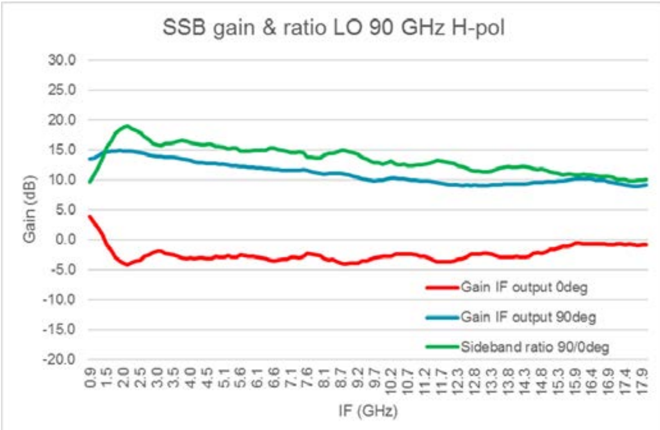


Fig. 5 Measured gain and sideband ratio of the 2SB receiver for a fixed LO frequency of 84 GHz, at the IF outputs of the V-polarization channel (top graph), and the H-polarization channel (bottom graph).

B. Noise figure response

Noise figure of the complete 2SB receiver for each polarisation has been characterised over the full 63-120 GHz range for each polarization. An example of test results showing the receiver noise temperature for both IF outputs (LSB & USB) of the H-polarization channel are presented in Fig. 6. The measured noise temperature is between 3000K and 8000K in the 4-12 GHz IF band.

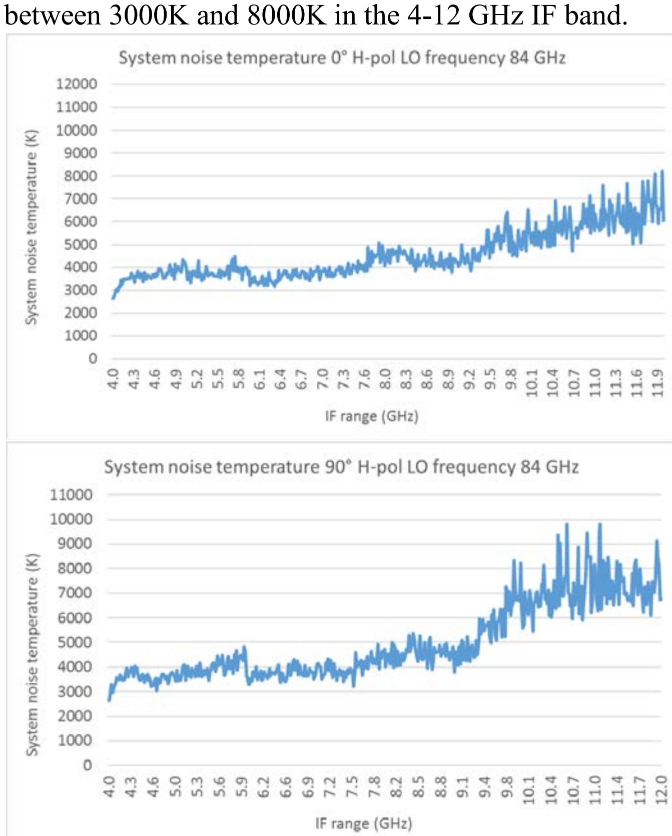


Fig. 6 Measured receiver noise temperature of the 2SB receiver for a fixed LO frequency of 84 GHz, at both IF outputs (LSB & USB) of the H-polarization channel.

C. Spurious emission at RF input

The input spurious emission at the RF waveguide input for both polarization in the WR10 and WR05 range using R&S spectrum analyser extender mixers. Results are presented in Table I. At the 6th harmonic of the fundamental LO signal, the maximum spurious level measured is -35 dBm on H-polarisation channel at 90 GHz. At the 12th harmonic of the fundamental LO signal, the maximum spurious level measured is -52 dBm on H-polarisation channel at 192 GHz. The performance of the out-of-band filter introduced at the RF input of the 2SB receiver has proven to reject the 2nd harmonic of the LO signal better than 22 dB.

TABLE I

LO input frequency	H-spurious 6*LO	V-spurious 6*LO	H-spurious 12*LO	V-spurious 12*LO
13.1 GHz	-41.5 dBm	-53 dBm	-68.3 dBm	-68.8 dBm
13.5 GHz	-41.4 dBm	-52.5 dBm	<-79 dBm	<-80 dBm
14 GHz	-41.8 dBm	-51 dBm	<-77 dBm	<-80 dBm
14.5 GHz	-31.5 dBm	-45.3 dBm	<-80 dBm	<-80 dBm
15 GHz	-35 dBm	-46.3 dBm	<-80 dBm	-70.8 dBm
15.5 GHz	-36.4 dBm	-46.4 dBm	<-80 dBm	<-80 dBm
16 GHz	-39 dBm	-61.2 dBm	-52 dBm	-64.9 dBm
16.5 GHz	-54.9 dBm	-60.2 dBm	-69.7 dBm	-65.6 dBm
17 GHz	-48.5 dBm	-61.1 dBm	-66.8 dBm	-64.6 dBm
17.3 GHz	-43.9 dBm	-63 dBm	-60.7 dBm	-66.1 dBm

CONCLUSION

An ultra-wideband 67-116 GHz dual-polarization sideband separating Schottky based receiver has been defined, prototyped and tested. The performance have been measured over the entire 67-116 GHz range, confirming the suitability of this technology for the ALMA Band 2+3 Warm Cartridge Assembly requirements. Further testing is on-going to characterize the short term gain stability (1/f noise).

ACKNOWLEDGEMENTS

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