RxA3m Sideband Ratios Spring 2016

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1 Introduction

The ASIAA mixer installed in RxA3 in December 2015 has different line intensities in the two sideband for a number of important lines. This shows that the sideband gains not are equal. In order to properly calibrate the observations the sideband ratio needs to be characterized. Further the RxA3m horn is not identical to the RxaA3 horn. The difference was compensated by shifting the mixer location relative the receiver optics. This compensation is not perfect and will generate a small change in beam shape and efficiency. Hence, we should not expect identical line T_A^* to RxA3 even if the sideband gain differences in RxA3m are calibrated out.

The sideband ratio is measured by injecting the same intensity signal in either of the two sidebands for a fixed LO frequency. The ratio between the observed signals is the sideband ratio. Note that measuring the intensity of a specific line in the lower and then in the upper sideband not is a measurement of the sideband ratio since two different LO frequencies are used. The line intensities will depend on the sideband ratios at the two different LO frequencies. Thus the sideband ratio can not be found by dividing the intensity of same line observed in the upper and lower sideband.

Gain differences between the two sidebands are introduced by differences in the wave propagation before the mixer as well as differences in the mixer. The atmosphere, optics, horn and wave guide will propagate the two sideband differently to a variable degree. In the best case the differences are small. Further, the probe that sticks into the waveguide and extracts the signal can couple differently to the two frequencies. Then the circuit between the probe and mixer used for impedance matching has frequency dependence. A noticeable effect of the wave guide is that the power not absorbed by the probe continues down the waveguide until it is reflected at the backshort. This reflected power will again pass the probe giving rise to a frequency dependent variation in the field strength at the probe. An extreme example of an optical difference between the sidebands is a quasi optical single sideband (SSB) filter. The SSB filter trasmitts one sideband while the other sideband sees a load generating a gain difference between the sidebands of typically more than 10 dB.

No dual sideband mixer has a sideband gain ratio that is perfectly unity. In particular we should expect deviations at the end of the tuning range and sinusoidal variation due to the standing wave generated by the power not adsorbed by the probe. In a well designed system these variations are small.

2 RxA3

The only practical method we have to determine the sideband ratios in RxA3m is by comparing the intensities to the intensities observed by RxA3. Of course RxA3 being a dual sideband receiver

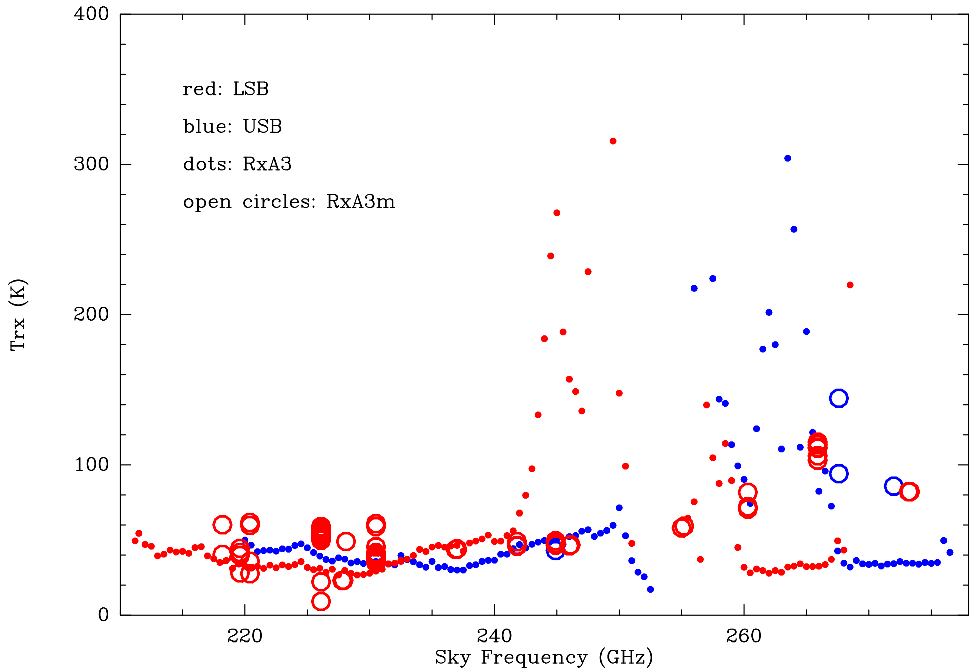

Figure 1: Trx for RxA3 and RxA3m as function of sky frequency. The effect of the 252 GHz notch in RxA3 can be seen in a 10 GHz range that are shifted between upper and lower sideband. Deviations from unit sideband rations are expected in the same ranges

also suffered from variations in the sideband gain ratio. However, for many important lines RxA3 had similar intensities when observed in upper and lower sideband. The clear exception is a region around 252 GHz. Some fault in the mixer cause a notch at about 252 GHz. This made it impossible to use and LO frequency around 252 GHz and generated very different sideband gains if one sideband was close to 252 GHz. See figure 1 for this issue.

3 Fitting a model

To determine the sideband ratio and the change in efficiency about 120 line intensities obtained by RxA3m were fitted to to agree with measurements of the corresponding lines with RxA. The fit optimizes the ratio between the gain in the lower l and upper sideband u (G_l/G_u) and a overall efficiency factor that was applied to the RxA3m line intensities. Also included was a number of HC_3N lines observed in both upper and lower sideband - for these lines it was only assumed the line intensity should be a linear function of the transition - the line intensities were fitted using two parameters. So in the case of these lines there is not an assumption RxA3 gives the correct answer. The correction applied to the RxA3m lines were $(1 + G_i/G_u)/2$ and $(1 + G_u/G_l)/2$ for the upper and lower sideband, respectively. The ratio G_i/G_u was modeled by a fifth order polynomial whith coefficients determined by the fit. The overall efficiency was modeled by a linear function of frequency but was found to be almost constant at 90%.

The relative errors are below about 20% up to about 240 GHz. Above this frequency relative errors up to almost 40 % occurs. The region of larger errors partly overlaps the region where RxA3 is know to have sideband problems. However, the overlap is not exact so while issues with RxA3 sideband ratios might play a role there are other factors contributing. No attempts has been to correct for the RxA3 sideband problems in this frequency range before the fit. Above 265 GHz the errors again is less than 20 %. The error in line intensities computed from the residual sum of squares is about 15%.

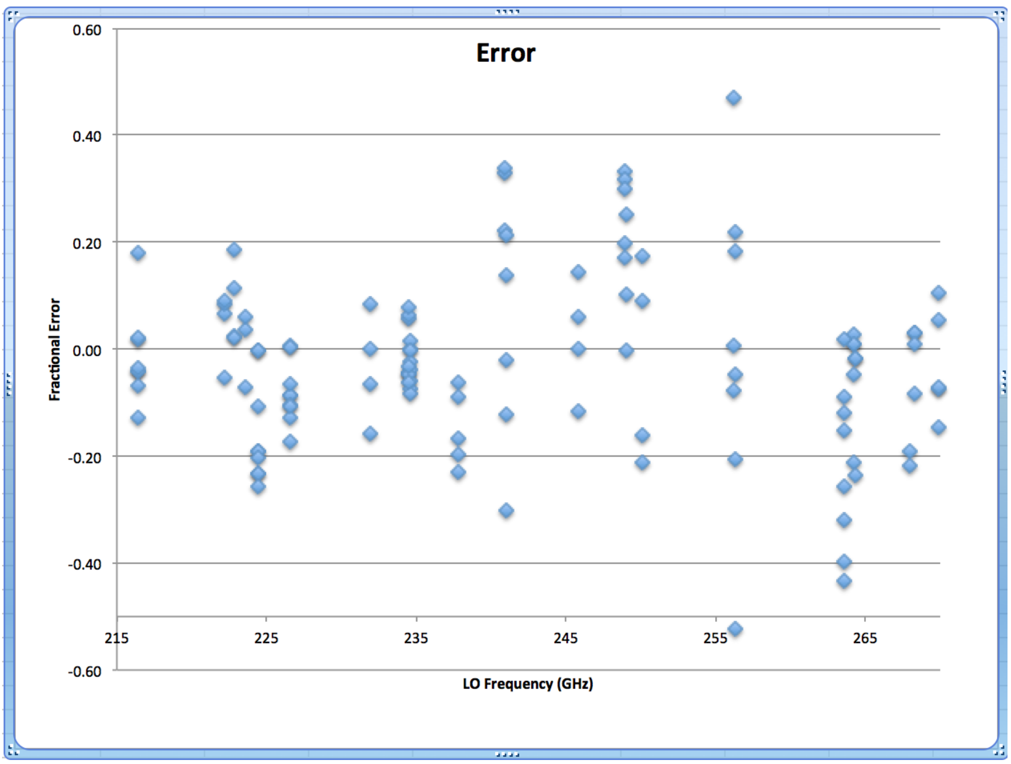

Figure 2: The fractional difference between the sideband and efficiency correct RxA3m intensity and RxA3 intensity for all the data points. I.e. $(corrected(I_{RxA3m}) - I_{RxA3})/I_{RxA3}$.

4 Flat Fielding

The continuum level from planets can be used to investigate the quality of the flat fielding across a spectra - assuming the planet spectra is flat. This often reveals a sinusoidal variation across the

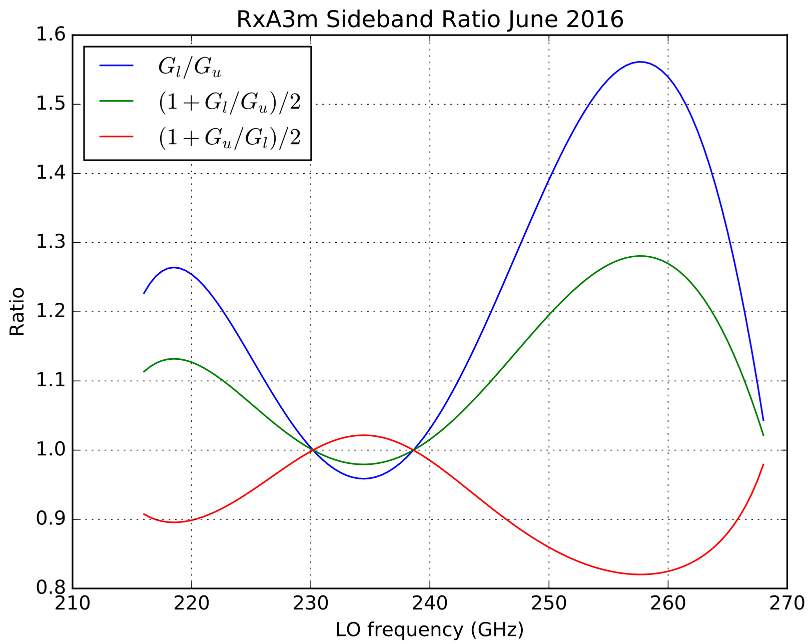

Figure 3: The fitted Sideband ration G_{lower}/G_{upper} and the corresponding correction factors. Upper sideband measurements should be corrected with $(1 + G_{lower}/Gupper)/2$ and the lower sideband with $(1+G_{upper}/Glower)/2$. In addition an overall efficiency factor between 80 and 90% in needed.

bandpass. For chopper wheel calibrated data the reason is standing waves between the calibration load and the receiver making the calibration load not to be flat across the bandpass. This give rise to calibration ripples across a continuum source like Jupiter. As can be seen in figure 4 and 5 the Jupiter spectra has a ripple of amplitude $\pm 5\%$. Under similar condition is was about 2% with the old RxA3 receiver. The variation in flat field is weather dependent. It really bad weather the standing wave amplitude is a larger fraction of the difference between the ambient load and the sky generating larger calibration ripple. Thus is really bad weather the calibration variation across the spectral band can be significant.

5 Correction

To correct the RxA3m line intensities to agree better with RxA3 intensities they should be divided by the efficiency factor of 0.9 and multiplied with the sideband factor $(1+G_i/G_s)/2$ where i stands for the image frequency and s for the signal frequency. Thus if the line is in the upper sideband the sideband correction factor is $(1 + G_l/G_u)/2$ and if the line is in the lower sideband the correction factor $(1 + G_u/G_l)/2$.

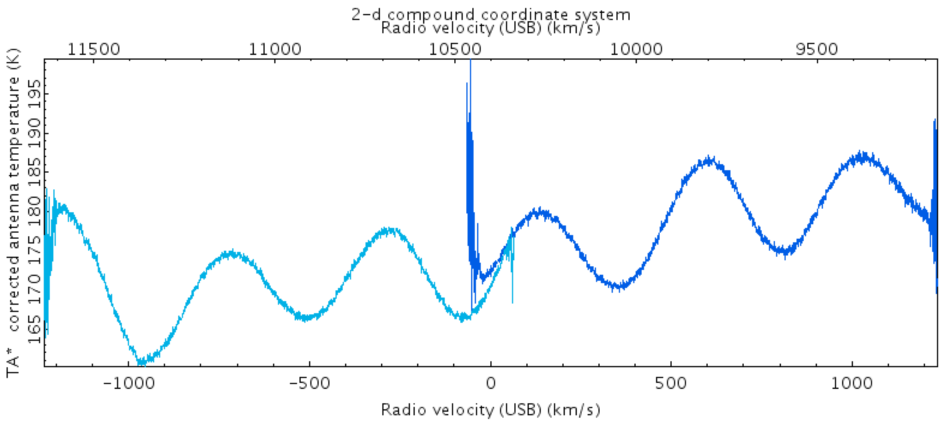

Figure 4: 1800 GHz Jupiter Spectra with an LO of 226.538 GHz

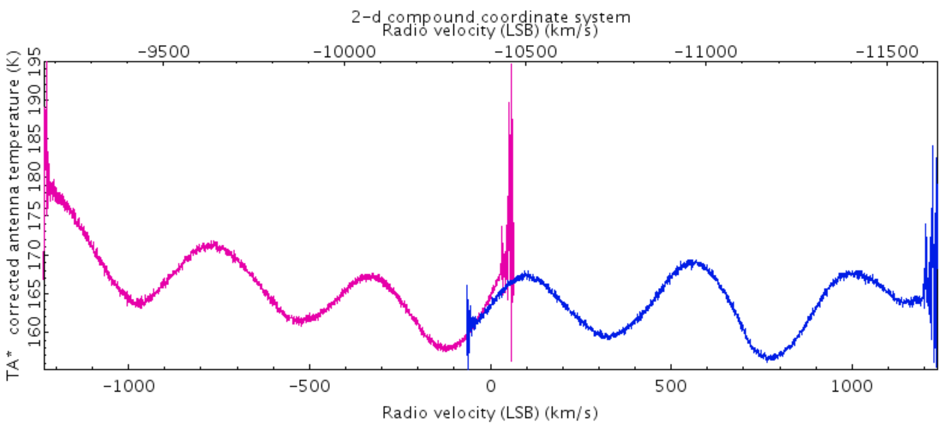

Figure 5: 1800 GHz Jupiter Spectra with an LO of 234.538 GHz

6 Note

The sideband correction factor is normally $1 + G_i/G_s$ but the online system has already applied this factor assuming that $G_i/G_s = 1$ i.e. have already multiplied the line with a factor of two. Thus we have to apply the factor $(1 + G_i/G_s)/2$ to correct for the sideband gain.

7 Appendix

LO (GHz)	G_l/G_u	$(1 + G_l/G_u)/2$	$(1 + G_u/G_l)/2$
216.0	1.23	1.11	0.91
216.5	1.24	1.12	0.90
217.0	1.25	1.13	0.90

217.5	1.26	1.13	0.90
218.0	1.26	1.13	0.90
218.5	1.26	1.13	0.90
219.0	1.26	1.13	0.90
219.5	1.26	1.13	0.90
220.0	1.25	1.13	0.90
220.5	1.25	1.12	0.90
221.0	1.24	1.12	0.90
221.5	1.23	1.11	0.91
222.0	1.22	1.11	0.91
222.5	1.20	1.10	0.92
223.0	1.19	1.10	0.92
223.5	1.18	1.09	0.92
224.0	1.16	1.08	0.93
224.5	1.15	1.07	0.94
225.0	1.13	1.07	0.94
225.5	1.12	1.06	0.95
226.0	1.10	1.05	0.95
226.5	1.09	1.04	0.96
227.0	1.08	1.04	0.96
227.5	1.06	1.03	0.97
228.0	1.05	1.02	0.98
228.5	1.04	1.02	0.98
229.0	1.02	1.01	0.99
229.5	1.01	1.01	0.99
230.0	1.00	1.00	1.00
230.5	0.99	1.00	1.00
231.0	0.99	0.99	1.01
231.5	0.98	0.99	1.01
232.0	0.97	0.99	1.01
232.5	0.97	0.98	1.02
233.0	0.96	0.98	1.02
233.5	0.96	0.98	1.02
234.0	0.96	0.98	1.02
234.5	0.96	0.98	1.02
235.0	0.96	0.98	1.02
235.5	0.96	0.98	1.02
236.0	0.96	0.98	1.02
236.5	0.97	0.98	1.02
237.0	0.97	0.99	1.01
237.5	0.98	0.99	1.01
238.0	0.99	0.99	1.01
238.5	1.00	1.00	1.00
239.0	1.01	1.00	1.00
239.5	1.02	1.01	0.99
240.0	1.03	1.02	0.99

240.5	1.04	1.02	0.98
241.0	1.06	1.03	0.97
241.5	1.07	1.04	0.97
242.0	1.09	1.04	0.96
242.5	1.10	1.05	0.95
243.0	1.12	1.06	0.95
243.5	1.14	1.07	0.94
244.0	1.16	1.08	0.93
244.5	1.18	1.09	0.93
245.0	1.19	1.10	0.92
245.5	1.21	1.11	0.91
246.0	1.23	1.12	0.91
246.5	1.25	1.13	0.90
247.0	1.27	1.14	0.89
247.5	1.29	1.15	0.89
248.0	1.31	1.16	0.88
248.5	1.33	1.17	0.88
249.0	1.35	1.18	0.87
249.5	1.37	1.19	0.86
250.0	1.39	1.20	0.86
250.5	1.41	1.20	0.85
251.0	1.43	1.21	0.85
251.5	1.44	1.22	0.85
252.0	1.46	1.23	0.84
252.5	1.48	1.24	0.84
253.0	1.49	1.25	0.84
253.5	1.50	1.25	0.83
254.0	1.52	1.26	0.83
254.5	1.53	1.26	0.83
255.0	1.54	1.27	0.83
255.5	1.54	1.27	0.82
256.0	1.55	1.28	0.82
256.5	1.56	1.28	0.82
257.0	1.56	1.28	0.82
257.5	1.56	1.28	0.82
258.0	1.56	1.28	0.82
258.5	1.56	1.28	0.82
259.0	1.55	1.28	0.82
259.5	1.55	1.27	0.82
260.0	1.54	1.27	0.82
260.5	1.53	1.26	0.83
261.0	1.52	1.26	0.83
261.5	1.50	1.25	0.83
262.0	1.48	1.24	0.84
262.5	1.46	1.23	0.84
263.0	1.44	1.22	0.85

263.5	1.41	1.21	0.85
264.0	1.38	1.19	0.86
264.5	1.35	1.17	0.87
265.0	1.32	1.16	0.88
265.5	1.28	1.14	0.89
266.0	1.24	1.12	0.90
266.5	1.19	1.10	0.92
267.0	1.15	1.07	0.94
267.5	1.10	1.05	0.96
268.0	1.04	1.02	0.98