RxA3m Sideband Ratios 2018

Per Friberg

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1 Introduction

A large amount of data was collected and reduced by Jan Wouterloot in the spring an early summer of 2018 to better characterize the sideband ratios of RxA3m. This was done by stepping the receiver in 1 GHz steps across the band in such a way the USB and LSB data was collected directly after each other. E.g. the receiver was tuned to 225 GHz (USB), 225 GHz (LSB), 226 GHz (USB), 226 GHz (LSB) etc. By obtaining the USB and LSB is close time proximity calibrations error due to pointing, focus or other factors are reduced. The observations were mainly of G34.3 but also OMC1 and IRC+10216 were observed. The rich spectra in these sources ensures a large number of lines observed in both upper and lower sideband. Further, a number of frequency settings where repeated on different dates. Occasionally these repeat observations had large changes in absolute calibration and/or the ratio between upper and lower sideband. This illustrates that there are a number of other factors affecting the calibration accuracy apart from the sideband ratio. It should also be noted that the majority of the lines were weak so S/N is a factor. Keep in mind that the sideband gain ratio does not dominate the calibration accuracy so applying the sideband ratio correction do not guaranty an accurate calibration. Note also that beam efficiency of RxA3m is about 90% of the RxA3i beam efficiency.

In 2016 another fit to sideband data was produced. That fit assumed that the previous mixer (RxA3i) had a sideband ratio of one ($G_i/G_u = 1$) away from the know problematic area around 252 GHz. This is an approximation but made it possible fit the collected data to a model. Additional data was also used which not assumed the previous mixer (RxA3i) had a sideband ratio of 1. This included observations of HC_3N which has lines spaced about 9 GHz and some data collected as described above. The latter data was also used in the current (2018) fit. Analysis in 2017 showed that RxA3i did have significant differences from a sideband ratio of one even away from 252 GHz. This was particular apparent at higher LO frequencies, even of the data had large uncertainties. The finding motivated the current investigation. As apparent in figure 1 the 2016 and the current 2018 fit deviates significantly at higher LO frequencies. A general trend with G_l/G_u being larger than one in both mixers, at higher frequencies, could explain the deviation. It should be kept in mind that there is, for higher LO frequencies, gaps in the data both for the old and new mixer.

2 Result

A comparison between the 2016 fit and the current fits are shown in 1. In total 132 line ratios has been used in the current fits. In order to get an illustration of the errors involved in the derived

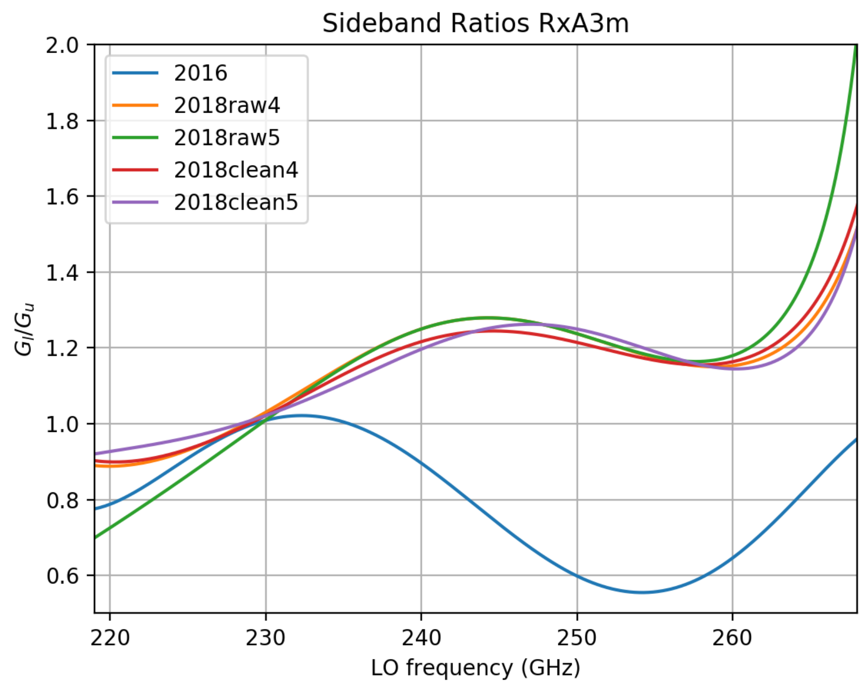

Figure 1: The fitted G_l/G_u ratio. The blue curve is the fit from 2016. The four other curves are fits using a 4th (raw4 & clean4) or 5th (raw5 & clean5) order polynomial off all (raw) or a cleaned set of data (clean) . To generate the clean data set the 6 largest outliners were removed after fitting the sideband ratio to the raw data set. These 6 points had a relative error in G_l/G_u of 20% or more. As can be seen removing the assumed bad data do not change the fit significantly. The difference between a 4th and 5th order polynomial fit is not large. In these fits the data was weighted by the estimated accuracy of each line ratio based on the noise in the spectra. However, a minimal error of 10% was imposed. The squared sum of weighted errors was only marginal better for a 5th than a 4th order fit, while a 3rd order polynomial fit had a significant higher sum of weighted squared errors. Showing that the noise dominates after a 4th order polynomial fit.

correction the correction was applied to all the lines in the data set. The resulting USB intensity was subtracted from the LSB intensity each line. Finally the difference was divided by the sun of the USB and LSB intensities. The resulting plot shows how effective the estimated correction is in making a line observed in the upper and lower sideband equal. Within the noise there is no clear trend in the errors. The errors computed this way is shown in 2. The model used is the raw4 model. Since the differences between the 4 current models not are large the lowest order and least edited fit was selected for usage.

To investigate the sensitivity of the model a jack knife test was performed. The data set was divided into two sets by selecting alternating rows in the raw data file. These two sets were fitted independently. The fitted G_l/G_u curves are shown in figure 3. The deviations are small - the only

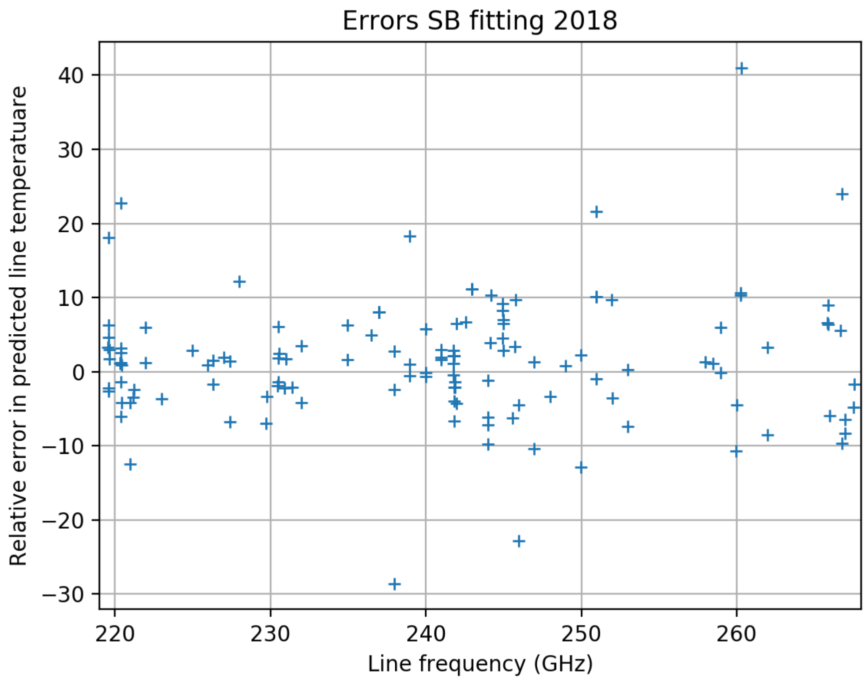

Figure 2: The effectiveness of the correction in making a line observed in the upper or lower sideband equal expressed in % of the line intensity. Note that the raw data set has been displayed so points that clearly deviates from the fit are included. The data points removed in the clean set is the points with relative error larger than 20% in the figure. The scatter in the plot is close to the 10% assumed as the intrinsic error in the data. The squared sum of the weighted error was ~ 236 for the raw data set. If the errors used in the weighting are realistic we expect this sum to be close to the number of data points. This is the case for the fit to the clean data set which had a squared sum of the squared errors of 148 compared to 126 points.

fit that deviates is the fifth order polynomial fit to the data set that consist of all odd lines in the raw data file.

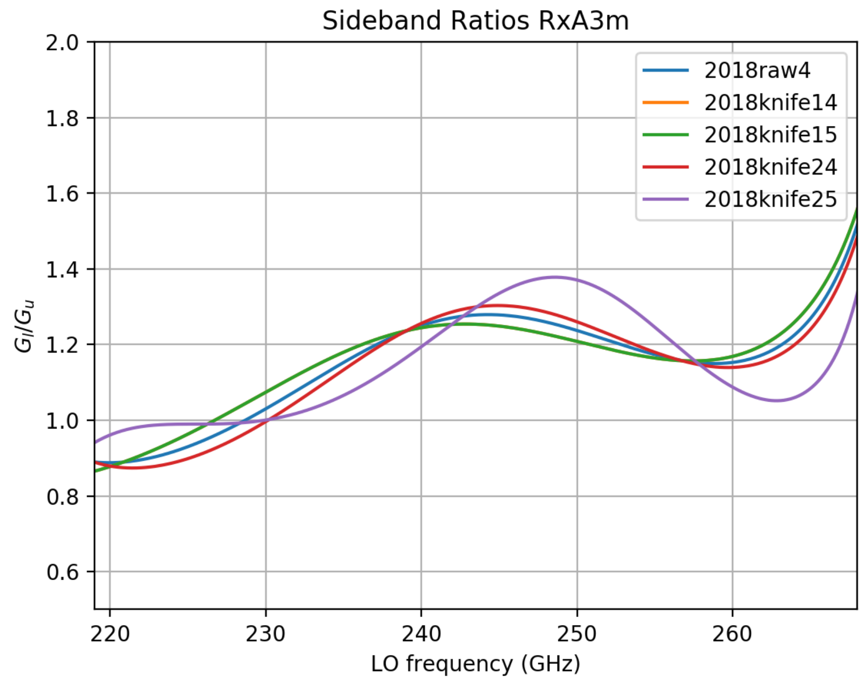

Figure 3: G_l/G_u for the main fit (raw4) and 4th and 5th order polynomial fits to the divided data. knife14 is the 4th order fit to all odd numbered rows in the raw data file and knife15 the 5th order fit to the same data set. Similar knife24 and knife25 are the 4th and 5th order fit to all even numbered rows in the raw data set, respectively. The orange knife14 line is hidden under the green knife15 line. Using the clean data makes such a small difference that the plotted lines would overlap with the lines in the current graph

Another way to display the effect of the model is to plot T_A^* in the LSB against T_A^* in the USB for the raw and corrected data. Such a plot should in a perfect world be a straight line with $T_A^*(\mathrm{LSB}) = T_A^*(\mathrm{USB})$. This relation is shown in figure 4. The correction tightens up the relation but do not fix all problems. As noted before the sideband ratio is just one of a number of factors that effect the calibration.

3 Discussion

The JCMT online data acquisition system assumes a sideband ratio of 1 for a DSB receiver. Hence, each DSB spectra is multiplied with $1 + G_i/G_s = 1 + 1 = 2$. Here G_i is the gain in the image sideband (the one you not are interested in) and G_s the gain in the signal sideband (the sideband the line you are observing is in). Thus, to use another sideband gain ration the spectra have to be

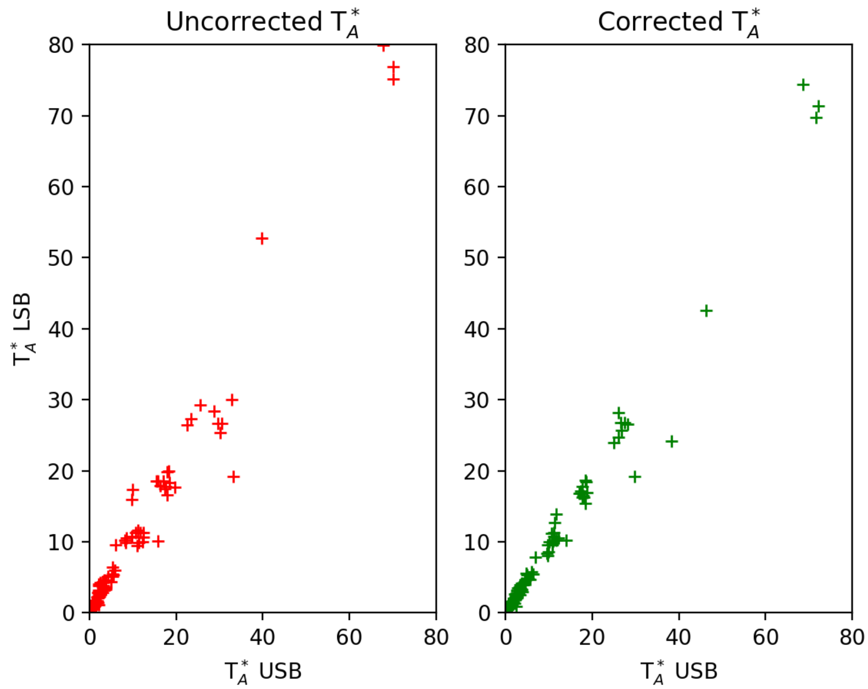

Figure 4: T_A^* in the LSB as function of T_A^* in the USB. The plot to the left shows the correlation before applying the correction and the right plot the correlation after applying the correction for the sideband gain. There is a clear improvement but as can be seen some discrepancies remains.

multiplied with $(1+G_u/G_l)/2$ for a line in the lower sideband (LSB) and with $(1+G_l/G_u)/2$ for a line in the upper sideband (USB). The division by 2 removes the previous adjustment done under the assumption $G_i/G_s = 1$.

Strictly specking we should use $1+\frac{G_i}{G_s}e^{(\tau_s-\tau_i)A}$ where A is the airmass and τ_s and τ_i the zenith opacity in the image and signal sideband, respectively. In this report we have assumed the image and signal zenith opacity are equal. This is a reasonable approximation in the 1.3 mm band.

4 Fit

The equation for the raw4 fit is

$$G_l/G_u = 0.782164242 + 0.331811472 \times x + 54.63449674 \times x^2 - 313.5952557 \times x^3 - 4833.576982 \times x^4$$

where $x = (LO - 245)/245$

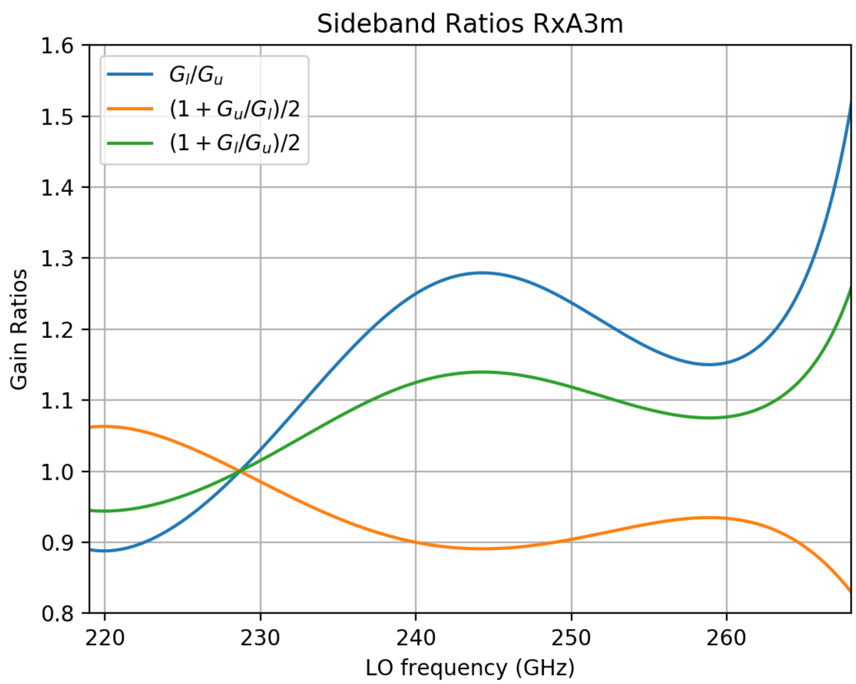

Figure 5: G_l/G_u, $(1 + G_l/G_u)/2$, $(1 + G_u/G_l)/2$. The raw4 fit from 1 has been used in this plot.