ALMA Science

What are the limits on observing multiple lines at edges of the IF or RF band (such as 12CO and 13CO2-1)?

Todd Hunter - 2020-09-21 - ALMA Observing Tool (OT)

In the ALMA system, no portion of the baseband or spectral window can lie outside of either the IF or RF range. This fact alone does not present any unforeseen limitations on what can be observed within the specified ranges. However, an issue arises because a spectral window has an **effective** bandwidth of only 15/16 (93.75%) of its total bandwidth, while no portion of its **total** bandwidth can lie outside of the baseband. This constrains the effective useable IF and RF ranges to:

IF_min,eff = IF_min + BW/32.0
IF_max,eff = IF_max - BW/32.0

RF_min,eff = RF_min + BW/32.0
RF_max,eff = RF_max - BW/32.0

where BW refers to the total spectral window bandwidth (as chosen from the set of 2, 1, 0.5, 0.25, 0.125, 0.0625 GHz), and the min and max IF and RF ranges are listed in the table below (all values are in GHz). You can also find this table in the ALMA Technical handbook, Table 4.1.

Band	Frequency/ Wavelength range (GHz)[1]/(mm)	LO range (GHz)	Sideband mode[2]	IF range (GHz)	Inst. IF bandw. (GHz)[4]	T_{rx} over 80% of band (K)[6]	T_{rx} at any frq. (K)[6]
3	84.0 - 116.0/ 2.59 - 3.57	92 - 108	2SB	4–8	7.5	<39[7]	<43[7]
4	125.0 - 163.0/ 1.84 - 2.40	133 - 155	2SB	4–8	7.5	<51	<82
5	158.0 - 211.0/ 1.42 - 1.90	166 - 203	2SB	4–8	7.5	<55	<75
6	211.0 - 275.0/ 1.09 - 1.42	221 - 265	2SB	4.5–10[3]	7.5	<83	<136
7	275.0 - 373.0/ 0.80 - 1.09	283 - 365	2SB	4–8	7.5	<147	<219
8	385.0 - 500.0/ 0.60 - 0.78	393 - 492	2SB	4–8	7.5	<196	<292
9	602.0 - 720.0/ 0.42 - 0.50	610 - 712	DSB	4–12	7.5(15)[5]	<175 (DSB)	<261 (DSB)
10	787.0 - 950.0/ 0.32 - 0.38	795 - 942	DSB	4–12	7.5(15)[5]	<230[8] (DSB)	<344 (DSB)

Table 4.1: ALMA Receiver Specifications. *Notes to Table:* **1.** Frequency ranges are the maximum available, at the extreme upper and lower limits of the IF passband. In reality, because of filter roll-off, the coverage is ∼60MHz less (See Section 6.4) **2.** Sideband modes: SSB means single sideband receiver, 2SB means dual sideband receiver where the two sidebands are available simultaneously, DSB means double sideband receiver. See text for details. **3.** Usable IF range is extended to allow simultaneous observations of multiple lines. However, the autocorrelation noise performance is degraded by a factor of up to about 1.2 below 5.5 GHz (Section 4.2.4) **4.** Maximum instantaneous IF bandwidth, limited by the back-end filters and spectrometers. As both upper and lower sidebands both pass through the same IF bandwidth but are subsequently separated, the effective signal bandwidth given in this column for 2SB receivers is twice the actual IF filter bandwidth. In addition, this is per polarization, so the total effective bandwidth for each receiver is then another factor of 2 higher. Note that the effects of the anti-aliasing filters have been included (see Section 6.4). **5.** In Cycle 6, the maximum bandwidth is approximately double in cross-correlation mode, because both sidebands can be separated and correlated using 90-degree phase switching (see Section 6.3.4 and Section B.4.4). **6.** The *maximum* specified SSB receiver temperatures (T_{rx}) are given, unless otherwise noted. These values are the average over the whole IF band. In many cases, the average realised results are better than specifications; the sections on individual receiver bands describe the typical values measured. The numbers adopted in the observing tool (OT) and ALMA sensitivity calculator (ASC) are conservative values of the average value over the band. **7.** The specification for Band 3 receivers are described slightly differently to other bands: at LO1=104GHz, T_{rx}<39 K (including warm optics), and T_{rx}<43 K for any other valid LO setting. **8.** The specification for Band 10 receivers is T_{rx}<230 K within a selected 80 % portion of that band (787–950 GHz).

While there is ongoing discussion to relax this requirement, it currently restricts how close one can place a spectral window to the receiver band edge (RF) and to the baseband edge (IF). These restrictions are correctly implemented in the OT. The most obvious restriction comes in situations where you want to observe two lines at the extreme edges of the IF range. The 12CO(2-1) and 13CO(2-1) lines are a particularly important example. Here the lines are so close together that you must place both lines in the IF near the lower limit of 5 GHz. Thus, the velocity space available around the lines is quite limited, particularly when using the broadest spectral windows. As the spectral window bandwidth is reduced, the effective edge of the window gets closer to the true edge of the IF range, allowing a little more freedom. Below are three tables which define the usable range of IF for the various combinations of Band and spectral window. The specific case of 12CO(2-1) and 13CO(2-1) is shown explicitly in the Band 6 Table, including the central frequencies to use when defining spectral windows which will place these two lines equidistant from the band edges. Please note that if the redshift is different to 0, you may have to vary slightly the figures in the table.

As of the start of Cycle 6, the Band 6 IF bandwidth has been increased by 0.5 GHz to extend from 4.5 to 10 GHz. This will enable12CO,13CO and C18O J=2-1 to be observed

simultaneously with broader spectral windows. In the Band 6 table below, for all spectral window equivalent bandwidths the spectral window central frequencies are 218.2185 GHz for 13CO 2-1 and 232.7185 GHz for 12CO 2-1.

There is also a known bug in the OT which affects spectral setups where the spectral windows are at the extreme edges of the IF. This means that the frequencies given below may have to be changed slightly (by fractions of a MHz) in order for a tuning to be found, in the sense that the spectral window should be moved away from its sideband edge. For example, the Band-6 setting given below for the 117 MHz-wide spectral window would work (for zero velocity) with frequencies of 220.4060 and 230.5311 GHz (a change of 100 kHz in the higher-frequency spectral window).

Spectral window	Bands 3,4,5,7 and 8		Bands 9 and 10	
bandwidth	Lowest IF accessible	Highest IF accessible	Lowest IF accessible	Highest IF accessible
(MHz)	(GHz)	(GHz)	(GHz)	(GHz)
1875	4.0625	7.9375	4.0625	11.9375
937.5	4.0313	7.9688	4.0313	11.9688
468.75	4.0156	7.9844	4.0156	11.9844
234.375	4.0078	7.9922	4.0078	11.9922
117.1875	4.0039	7.9961	4.0039	11.9961
58.59375	4.0020	7.9980	4.0020	11.9980

Band 6 Effective Spectral Window Bandwidth (MHz)	Lowest IF accessible (GHz)	Highest IF accessible (GHz)	12CO & 13CO 2-1 Clearance of both lines from spectral window edge ** (MHz)	(km/s)
1875.0	4.5625	9.9375	507.000	659.30
937.500	4.5313	9.9688	538.250*	699.94*
468.7500	4.5156	9.9844	553.875*	720.26*
234.3750	4.5078	9.9922	561.688*	730.42*

117.1875	4.5039	9.9961	565.594*	735.50*
58.59375	4.5020	9.9980	567.547*	738.04*

*These windows are sufficiently narrow that the lines can be centered in them.

**The velocities are computed for the higher frequency line (12CO2-1)