
# ALMA Correlator Cycle 0

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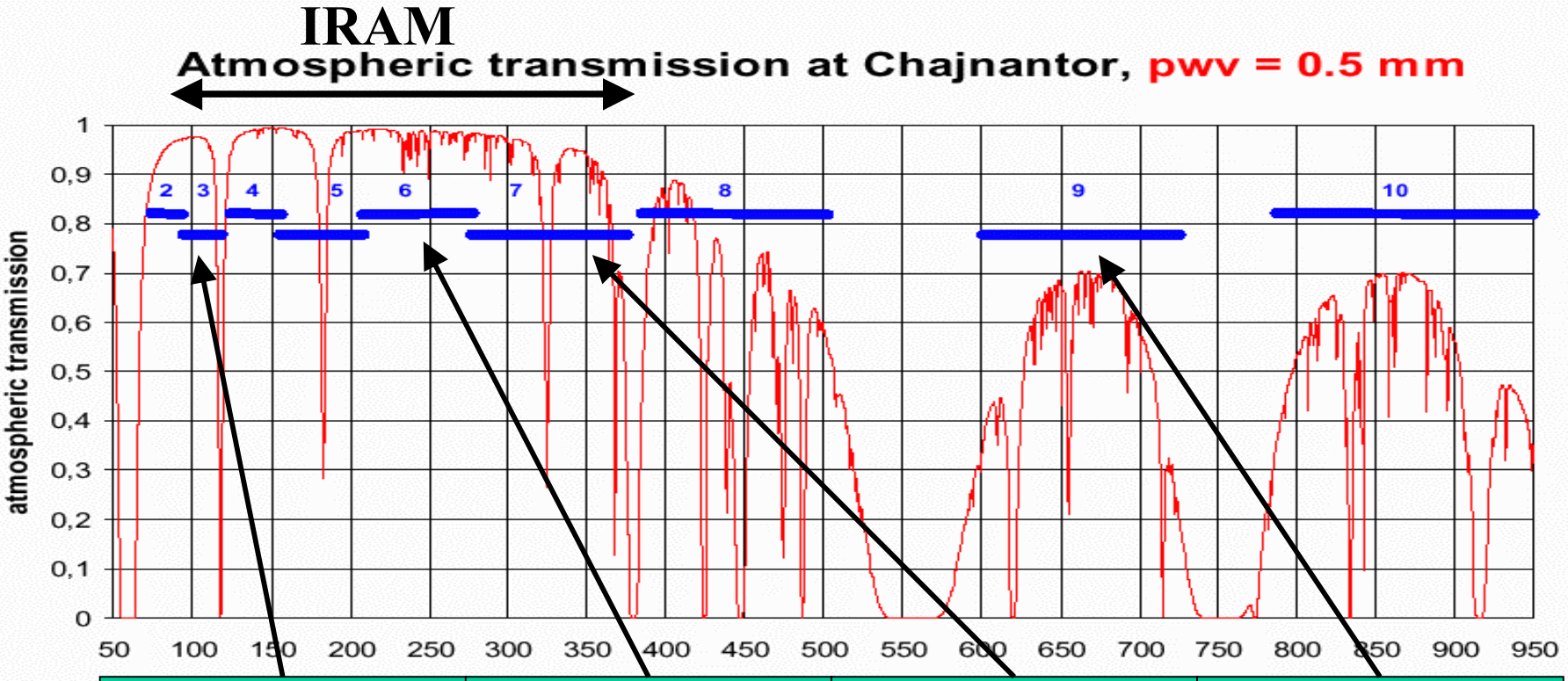
# Aim of this document

- This document aims at presenting a user-oriented description of the ALMA correlator modes for Cycle 0.
- It contains a few comparison with the IRAM system (which can be skipped by anybody not familiar with the Bure system).

- This document is **not a manual of the Observing Tool** – how to define a frequency/correlator setup with the OT is not described.

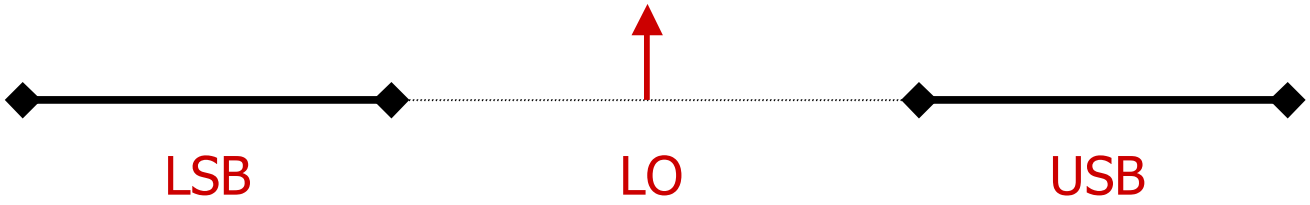
# Receiver bands




| Band 3 | Band 6 | Band 7 | Band 9 |
|---|---|---|---|
| 3mm window | 1.3mm window | 850 μm window | 450 μm window |
| 84-116 GHz | 211-275 GHz | 275-376 GHz | 602-720 GHz |
| ~ B1 IRAM | ~ B3 IRAM | ~ B4 IRAM | |

# Receiver bandwidth

**Heterodyne** receivers are sensitive to Lower Side Band and Upper Side Band




Receivers can be

- **DSB** outputs the sum LSB + DSB → separated in the correlator
- **SSB** outputs LSB **or** DSB
- **2SB** outputs LSB and DSB separately

# IRAM receivers

PdBI SSB receivers 4-8 GHz (4 GHz bandwidth LSB or USB)

EMIR090 2SB receivers 4-12 GHz (16 GHz bandwidth)

EMIR150/230 SSB receiver 4-8 GHz (4 GHz bandwidth LSB or USB)

EMIR330 2SB receivers 4-8 GHz (8 GHz bandwidth)

**Receivers have 4 to 16 GHz bandwidth**

**x 2 polarizations**

# ALMA receivers

ALMA B3 & B7 2SB receivers 4-8 GHz


ALMA B6 2SB receivers 5-10 GHz


ALMA B9 DSB receivers 4-12 GHz


**Receivers have bands 8 or 10 GHz bandwidth**

**x 2 polarizations**

# ALMA receivers

ALMA B3 & B7 2SB receivers 4-8 GHz


ALMA B6 2SB receivers 5-10 GHz


ALMA B9 DSB receivers 4-12 GHz


**B6 receivers have 10 GHz bandwidth – but only 8 GHz can be processed by the IF and correlator system**

**→ useful to allow simultaneous observations of multiple lines, esp. $^{12}$CO & $^{13}$CO (2-1)**

# ALMA receivers

ALMA B3 & B7 2SB receivers 4-8 GHz


ALMA B6 2SB receivers 5-10 GHz


ALMA B9 DSB receivers 4-12 GHz


**B9 are double sideband receivers – in Cycle 0, the two bands cannot be separated (Walsh)**

**… but one of the sideband can be suppressed (LO offsetting)**

# ALMA correlator

- ALMA correlator = **4 basebands**
- Each baseband processes
  - All antennas
  - 2 polarizations
  - **2 GHz input**

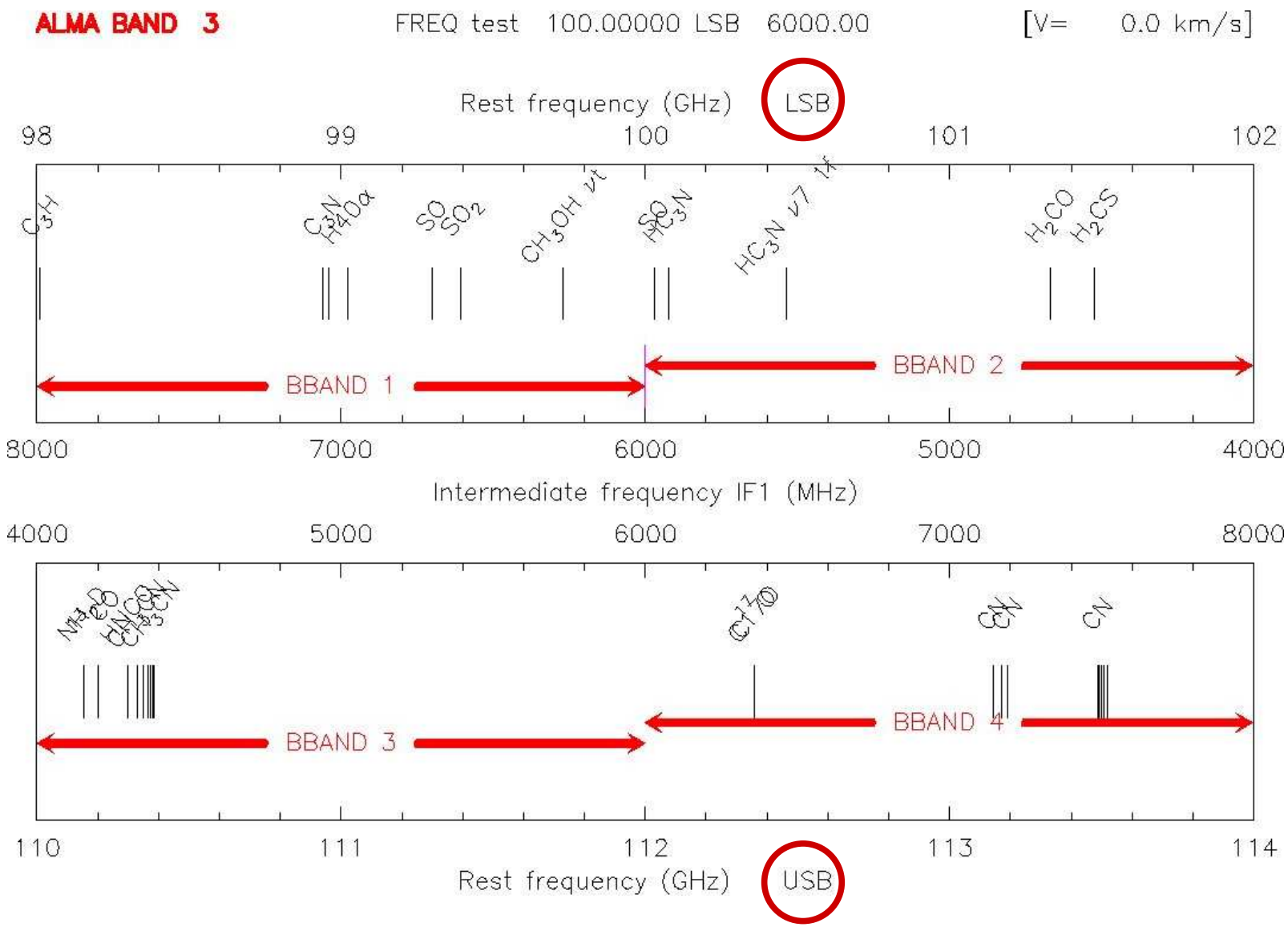
Can process incoming 8 GHz x 2 polarizations

- Each baseband can be centered anywhere* in the incoming 8 GHz
- All four basebands can be setup independently : gain on resolution / loss on bandwidth

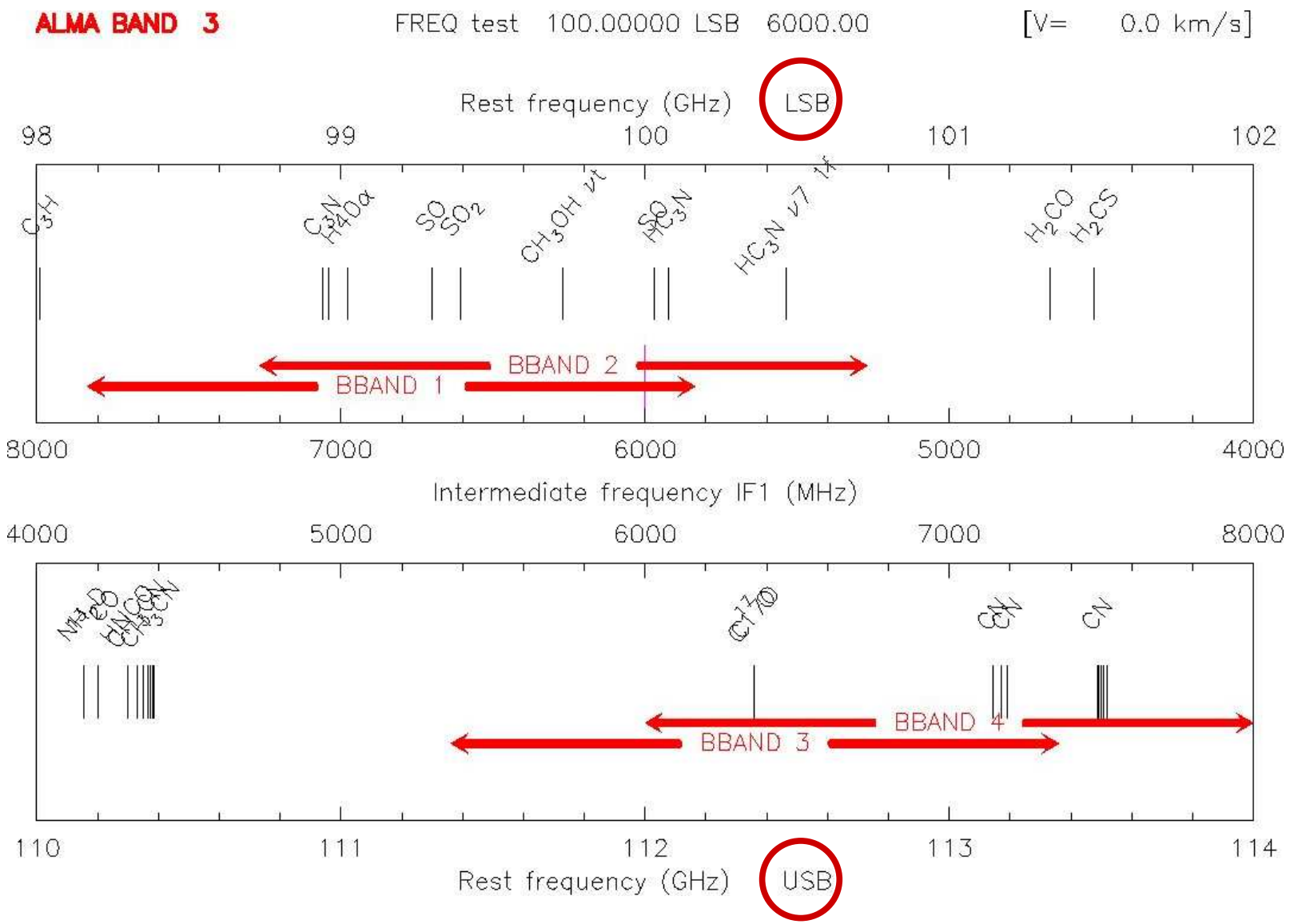
(* Minor limitations because of LOs finite step)

Higher spectral resolution but not on the full 8 GHz : spectral windows

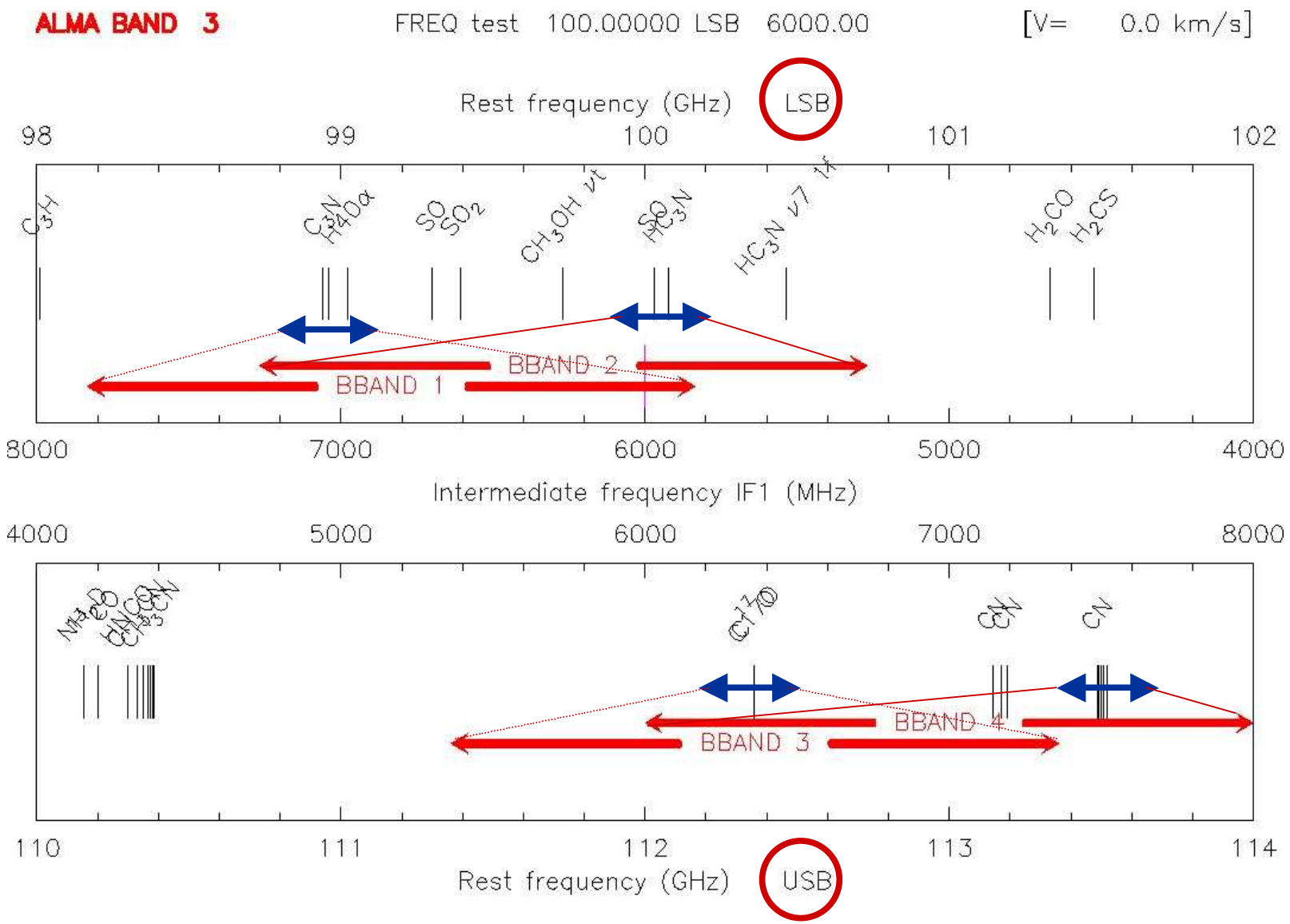
# Four basebands covering the 8 GHz



# Four overlapping basebands



# Four overlapping basebands giving four distinct spectral windows



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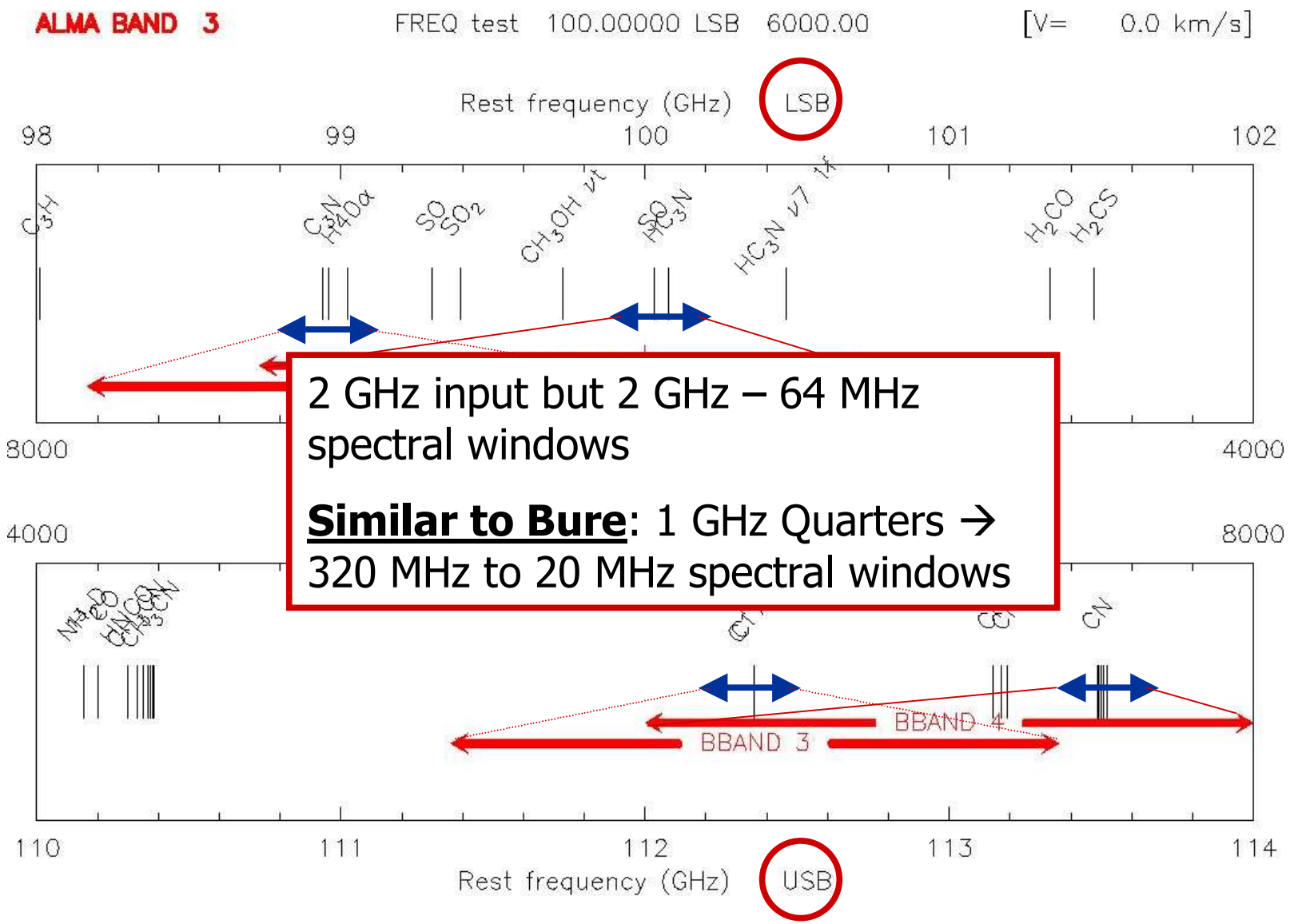
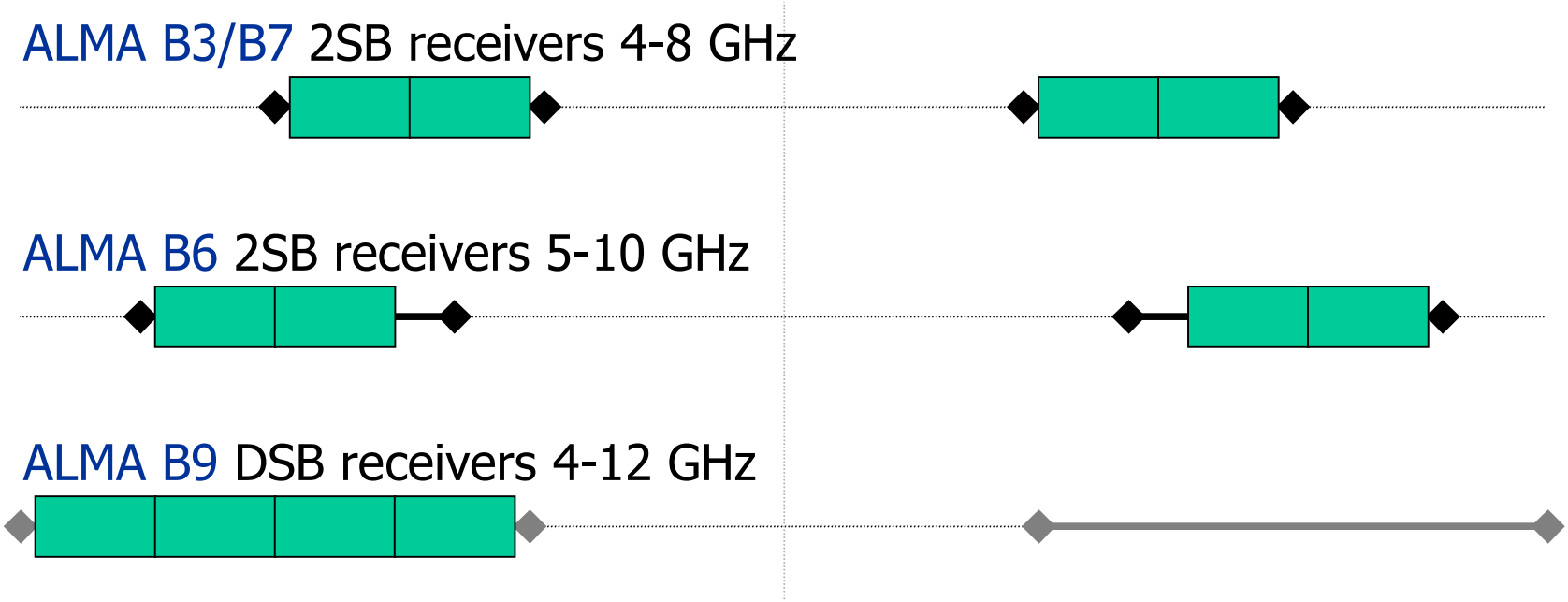


# Example

ALMA B3/B7 2SB receivers 4-8 GHz

ALMA B6 2SB receivers 5-10 GHz

ALMA B9 DSB receivers 4-12 GHz



Four basebands covering 8 GHz

Note B6 larger bandwidth (2x5 GHz)

# Example

ALMA B3/B7 2SB receivers 4-8 GHz

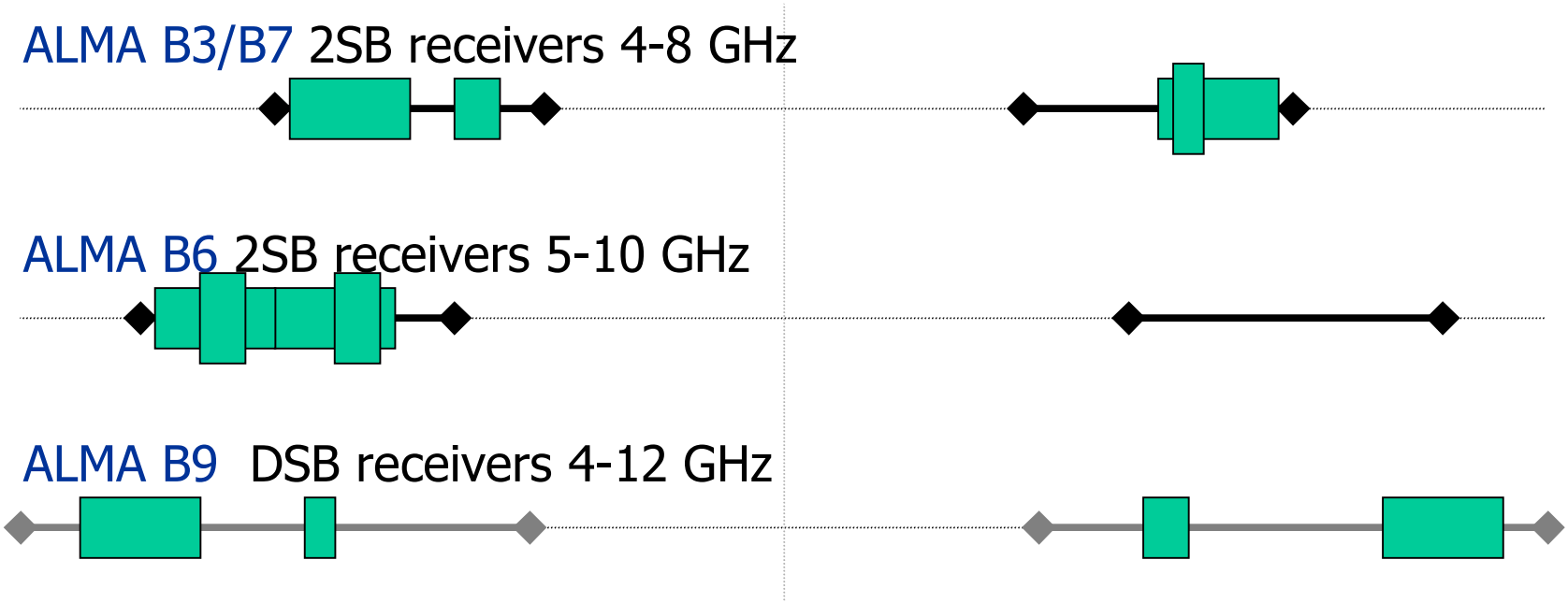
ALMA B6 2SB receivers 5-10 GHz

ALMA B9 DSB receivers 4-12 GHz

Four basebands with different width/resolution

B9: choice of LSB/USB (sideband supression) is done for each baseband

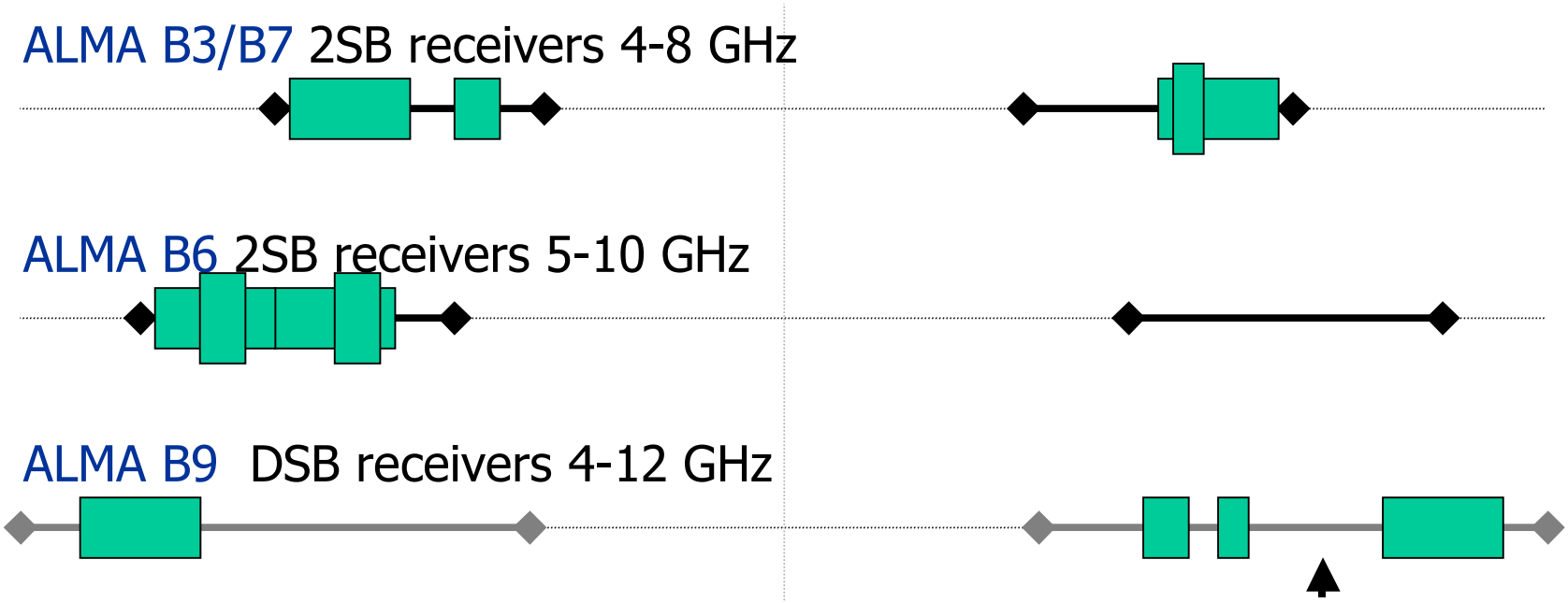
# Example




**Limitations**

- 2 GHz-wide basebands must lie within the receiver IF
- Spectral window must lie within baseband
- Center of spectral window must be at >50 MHz from baseband edge

# Example




**Basebands in LSB and/or USB?**

- **2SB receivers = B3/B6/B7 → only 4+0 or 2+2**
- **DSB receivers = B9 → 3+1 also possible**

# Basebands modes

1 polarization output (H or V)

- 2 GHz 8192 channels x 1 Pol x 244 kHz spacing
- 1 GHz 8192 channels x 1 Pol x 122 kHz spacing
- 500 MHz 8192 channels x 1 Pol x 61 kHz spacing
- 250 MHz 8192 channels x 1 Pol x 30 kHz spacing
- 125 MHz 8192 channels x 1 Pol x 15 kHz spacing
- 64 MHz 8192 channels x 1 Pol x 7.6 kHz spacing

**FDM**

- 2 GHz 256 ch. x 1 Pol x 7.8 MHz spacing

**TDM**

Frequency/Time division modes

# Basebands modes

1 polarization output (H or V)

- 2 GHz 8192 channels x 1 Pol x 244 kHz spacing
- 1 x 122 kHz spacing
- 5( x 61 kHz spacing
- 2[ x 30 kHz spacing
- 1[ x 15 kHz spacing
- 64 MHz 8192 channels x 1 Pol x 7.6 kHz spacing

**The spectral resolution is twice the channel spacing (Hanning smoothing – default)**

- 2 GHz 256 ch. x 1 Pol x 7.8 MHz spacing

# Basebands modes

2 polarization outputs (H and V)

- 2 GHz 4096 channels x 2 Pol = 488 kHz spacing
- 1 GHz 4096 channels x 2 Pol = 244 kHz spacing
- 500 MHz 4096 channels x 2 Pol = 122 kHz spacing
- 250 MHz 4096 channels x 2 Pol = 61 kHz spacing
- 125 MHz 4096 channels x 2 Pol = 30 kHz spacing
- 64 MHz 4096 channels x 2 Pol = 15 kHz spacing

- 2 GHz 128 ch. x 2 Pol = 15.6 MHz spacing

**Number of channels = 8192/Npolar**

# Basebands modes

4 polarization outputs (HH, VV, HV and V

- 2 GHz 2048 channels x 2 spacing
- 1 GHz 2048 chann kHz spacing
- 500 MHz 2048 244 kHz spacing
- 250 MHz 2 Pol = 122 kHz spacing
- 125 M s x 4 Pol = 61 kHz spacing
- 6 annels x 4 Pol = 30 kHz spacing
- 2 64 ch. x 4 Pol = 31 MHz spacing

**NOT OFFERED IN CYCLE 0**

**Number of channels = 8192/Npolar**

# Real bandwidths

## FDM modes

- Bandwidth edges are not used to avoid aliasing & edge effects
- **Effective bandwidth is 15/16$^{th}$ of the nominal width**
- **Real total number of channels is 7680 instead of 8192** (remaining channels are dropped within the correlator and not written in the data)

## TDM modes

- Filter in the IF chain limits the bandwidth to 1875 MHz
- FDM larger mode is already 2000 x 15/16 = 1875 MHz
- TDM: limits usable **bandwidth of continuum mode to 1875 MHz** (instead of 2000 MHz)

# Real bandwidths

## TDM modes

- Filter in the IF chain limits the bandwidth to 1875 MHz
- FDM larger mode is already 2000 x 15/16 = 1875 MHz
- TDM: limits usable **bandwidth of continuum mode to 1875 MHz** (instead of 2000 MHz)

## Consequence: ALMA Continuum sensitivity

- Maximal bandwidth for continuum is 4x1.875 = **7.5 GHz** (per polarization)
- This is taken into account in the OT Cycle 0 **update 1** (released early June 2011)

# Correlator Cycle 0

Proposers guide p.36

1 polarization output (H or V) – **actual channels numbers**

- 1875MHz 7680 channels x 1 Pol = 244 kHz resol.
- 938 MHz 7680 channels x 1 Pol = 122 kHz resol.
- 469 MHz 7680 channels x 1 Pol = 61 kHz resol.
- 234 MHz 7680 channels x 1 Pol = 30 kHz resol.
- 117 MHz 7680 channels x 1 Pol = 15 kHz resol.
- 58.6 MHz 7680 channels x 1 Pol = 7.6 kHz resol.

**FDM**

- Continuum mode 256 ch. x 1 Pol = 7.8 MHz resol.

**TDM**

# Correlator Cycle 0

Proposers guide p.36

2 polarization outputs (H and V) – actual channels numbers

- 1875MHz 3840 channels x 2 Pol = 488 kHz resol.
- 938 MHz 3840 channels x 2 Pol = 244 kHz resol.
- 469 MHz 3840 channels x 2 Pol = 122 kHz resol.
- 234 MHz 3840 channels x 2 Pol = 61 kHz resol.
- 117 MHz 3840 channels x 2 Pol = 30 kHz resol.
- 58.6 MHz 3840 channels x 2 Pol = 15 kHz resol.

FDM

- Continuum mode 128 ch. x 2 Pol = 15.6 MHz resol.

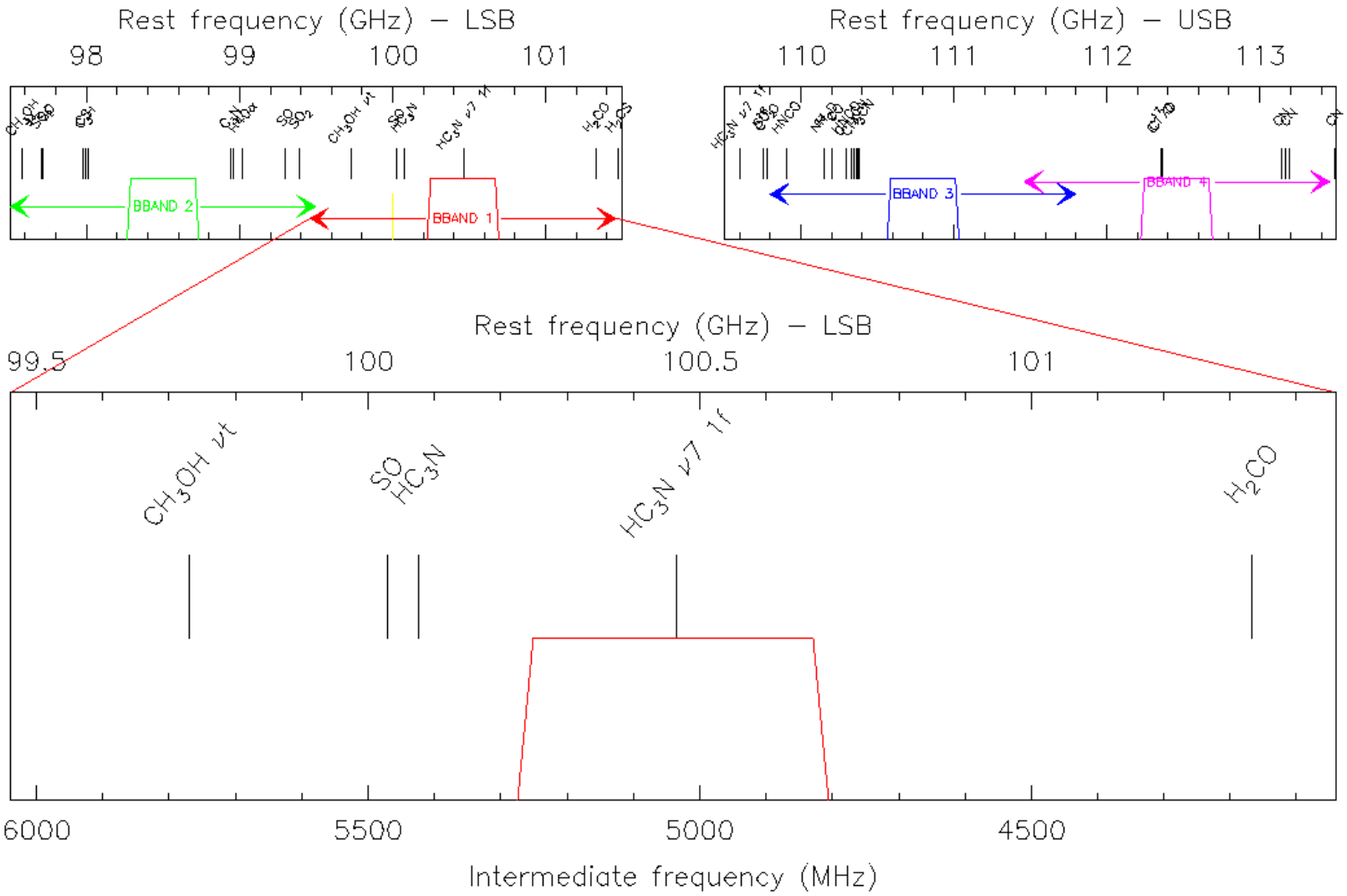
TDM

# Correlator Cycle 0

**All four spectral windows must share the same mode**

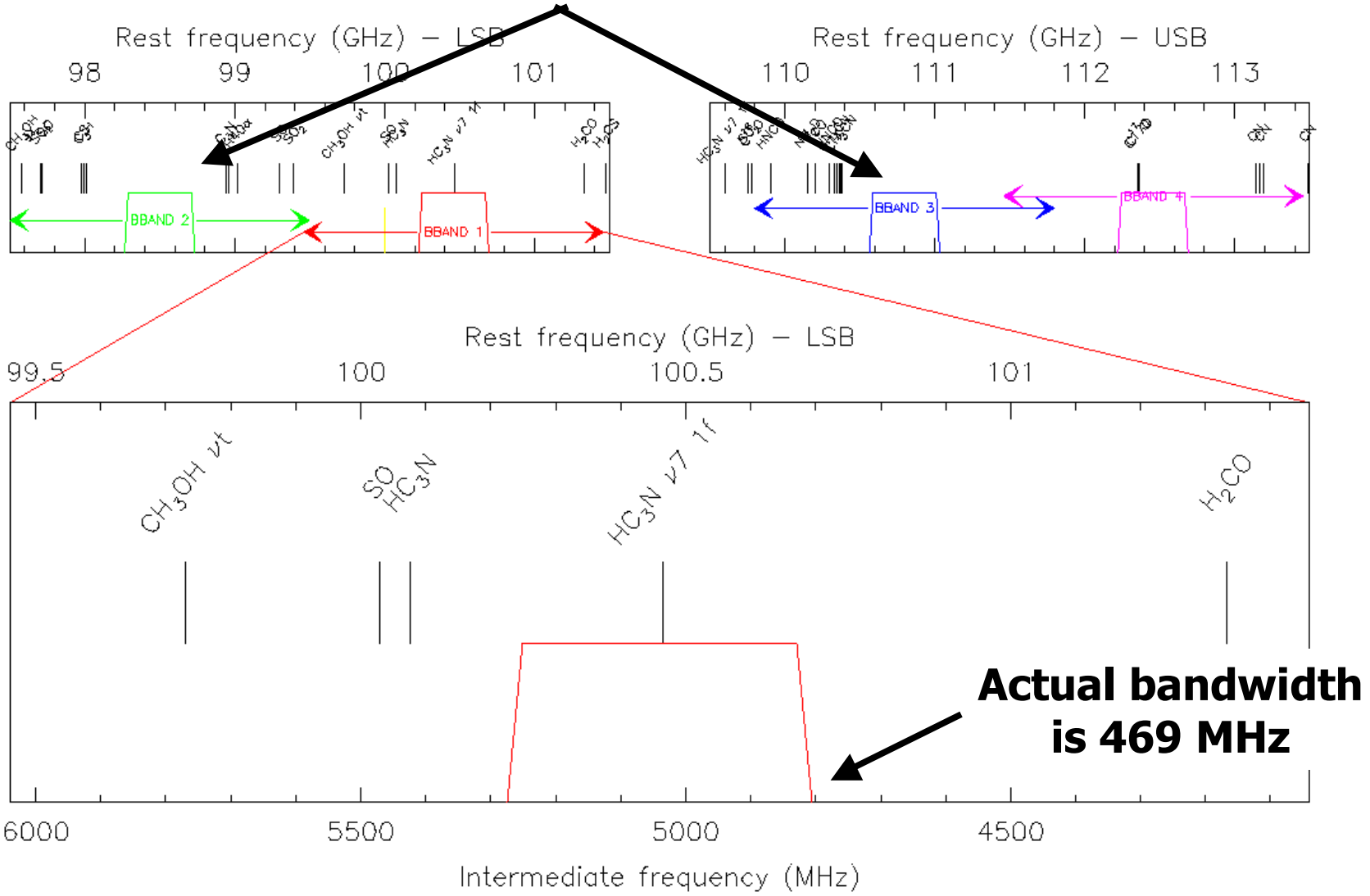
- Same **resolution/bandwidth** for the four spectral windows
  - Continuum & line? Must compromise!
- Same number of **polarization** products
  - Not a big issue
- **Same position within the baseband**
  - Making multi-line setups may be tricky if lines are near the edge of the receiver bandwidth

Technical Handbook table 8 p. 103, rules 6 & 7




**Spectral window chosen for baseband 1 → the four spectral windows will be 500 MHz/1 Polar/centered in baseband**

# Spectral windows basebands 2 & 3 are for continuum




**Spectral window chosen for baseband 1 → the four spectral windows will be 500 MHz/1 Polar/centered in baseband**

# Limitation Cycle 0

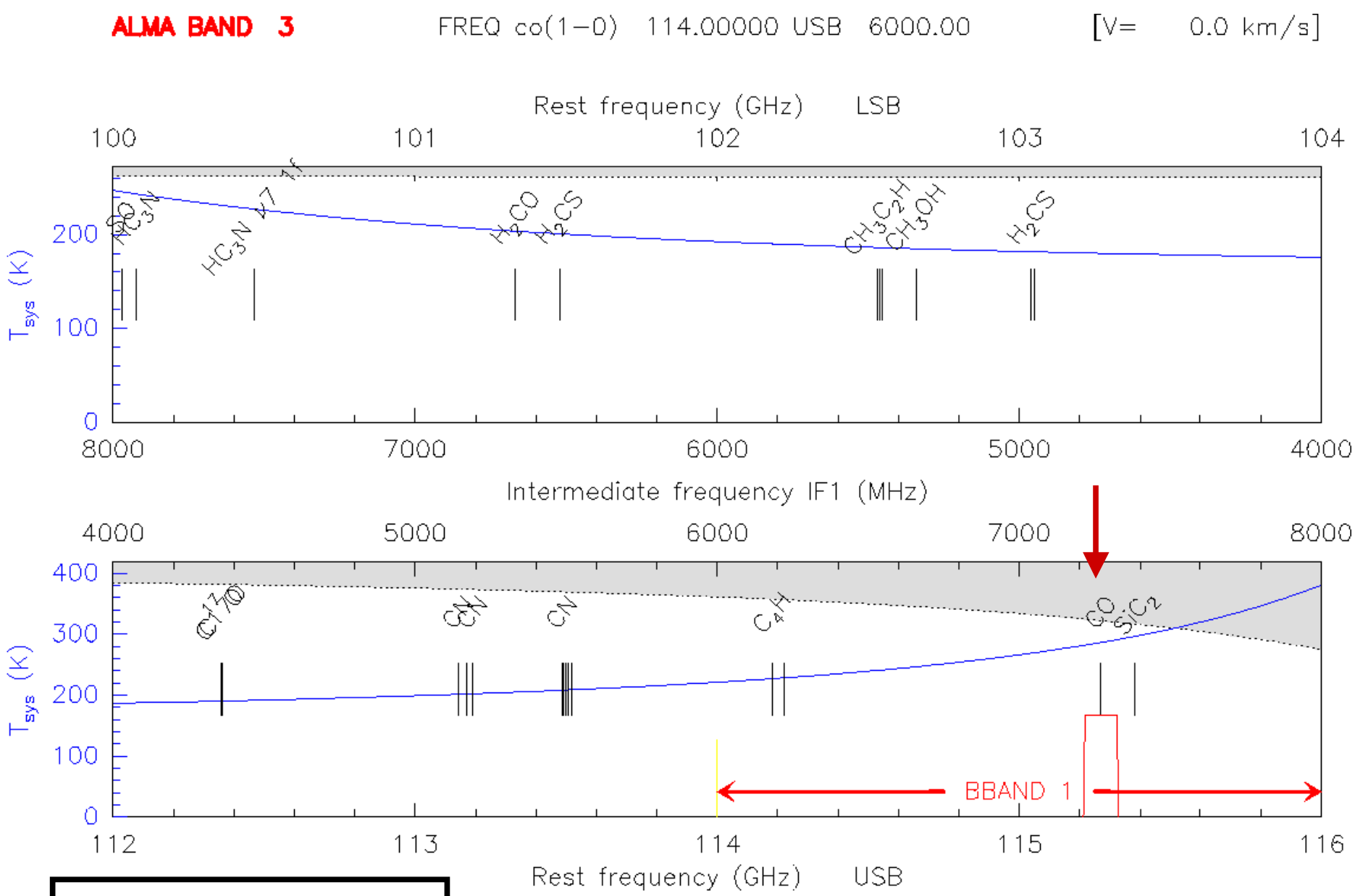
The four spectral window share the **same position within the baseband** – is that a serious limitation?

Simple solution: center spectral window in basebands, and center the basebands on the right position (line of interest)

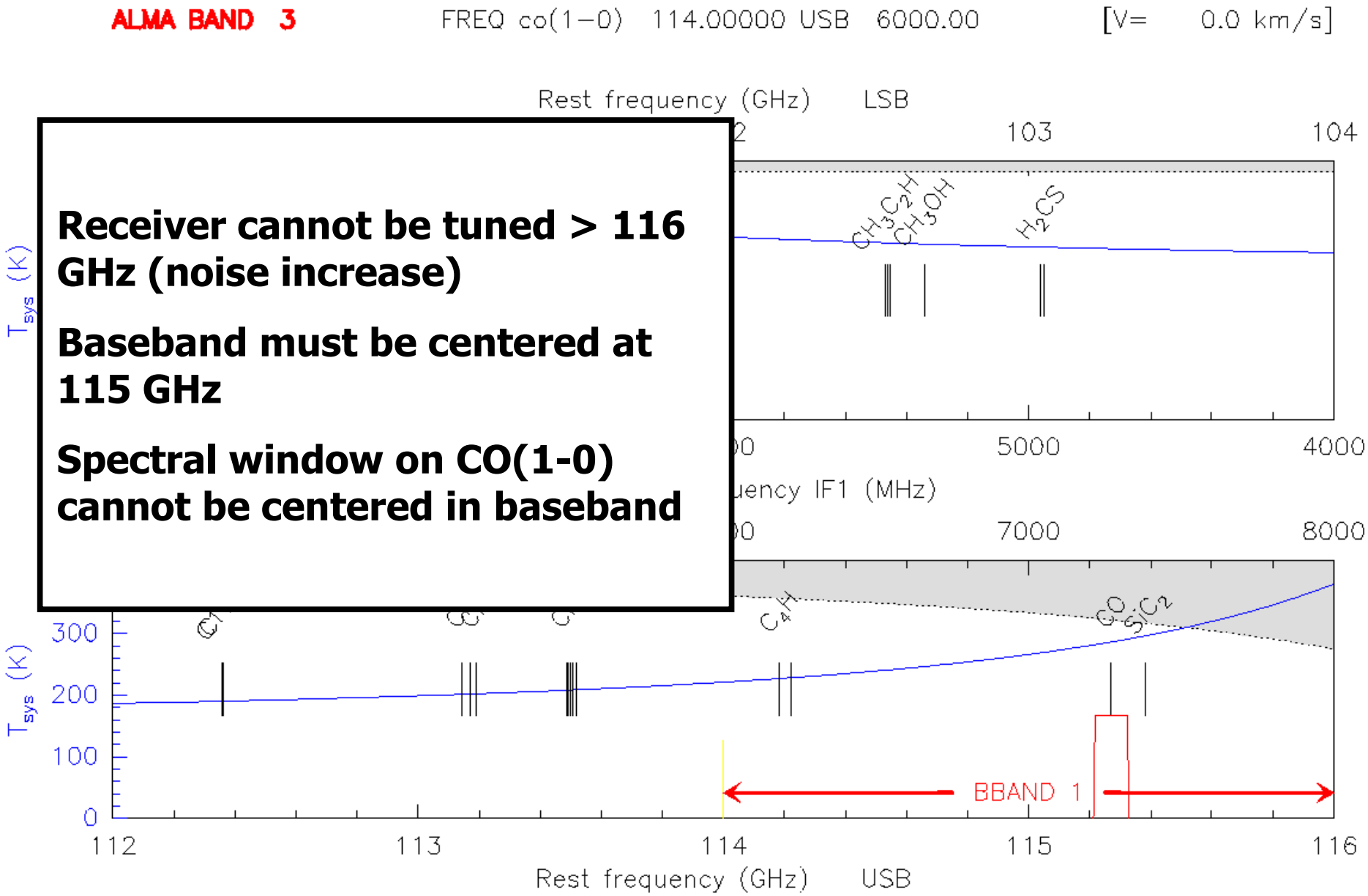
Problem if line to be observed is **near the edge of the IF bandpass** of the receiver

Two important cases: CO(1-0) at 115.3 GHz (B3)

$^{12}$CO(2-1) + $^{13}$CO(2-1) at 230/220 GHz (B6)



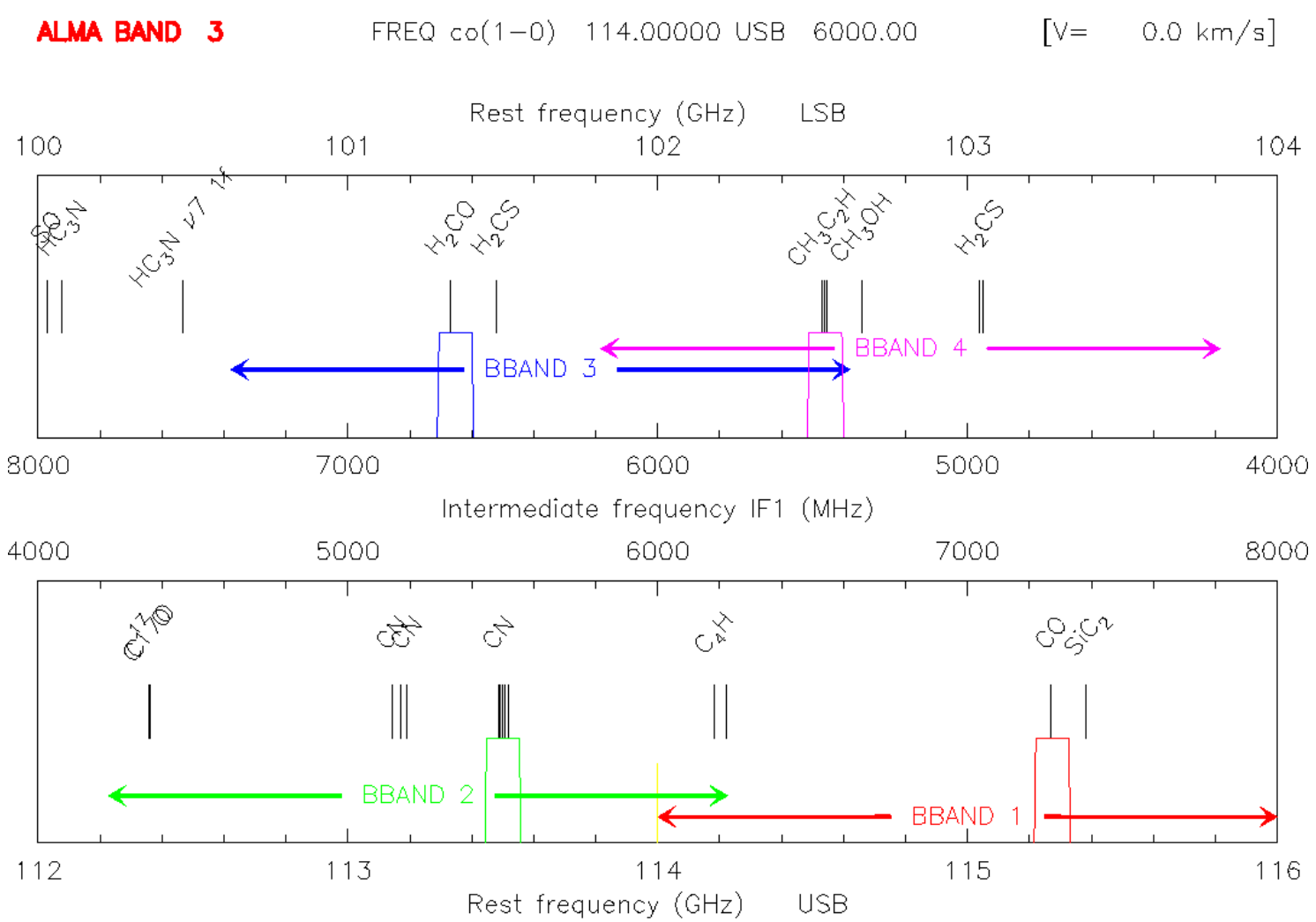

**$^{12}$CO (1-0) with B3**




**Receiver cannot be tuned > 116 GHz (noise increase)**

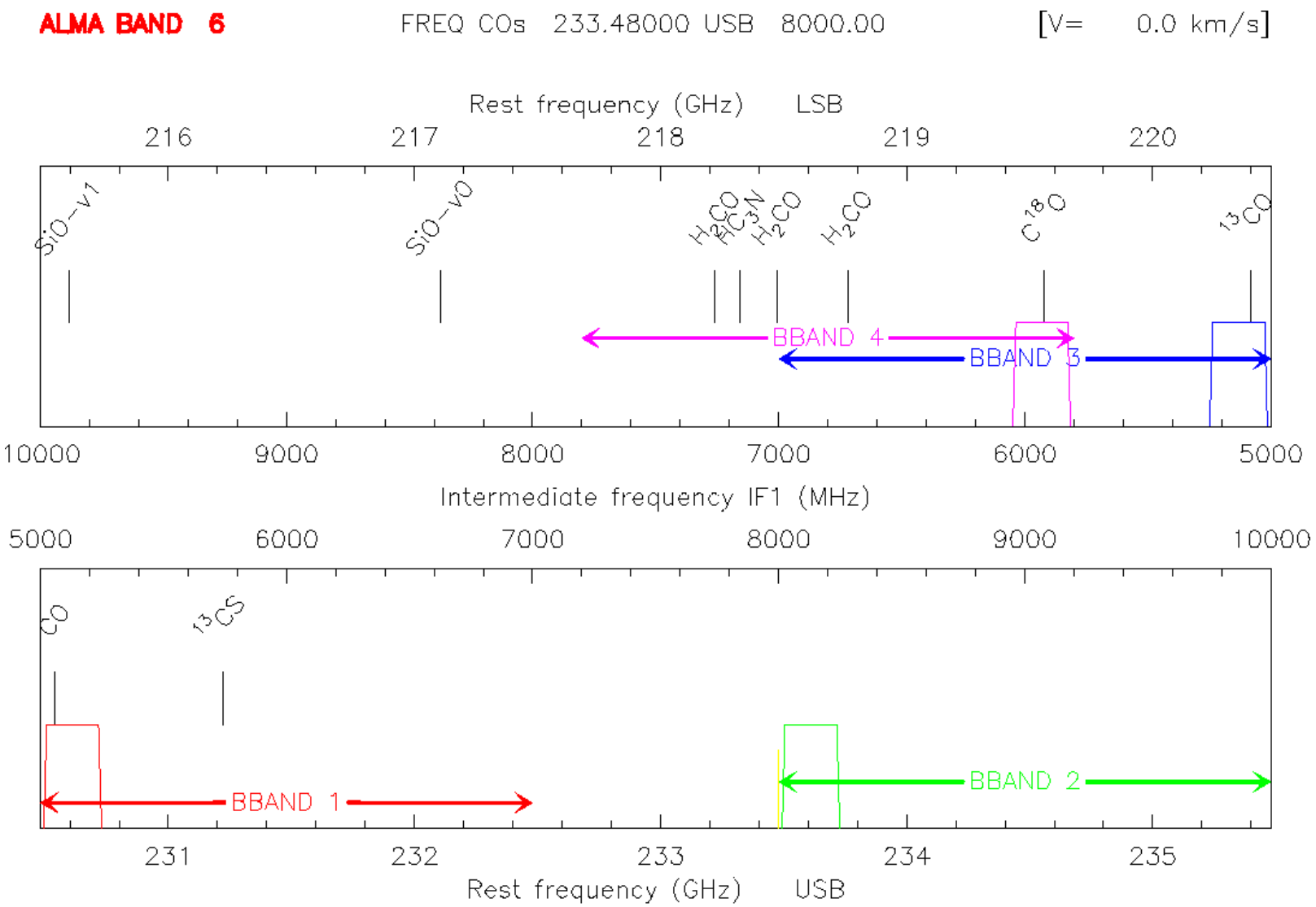
**Baseband must be centered at 115 GHz**

**Spectral window on CO(1-0) cannot be centered in baseband**




**Position of spectral windows in other basebands is fixed**
**Position of basebands can be moved**
**But not all lines can be reached**

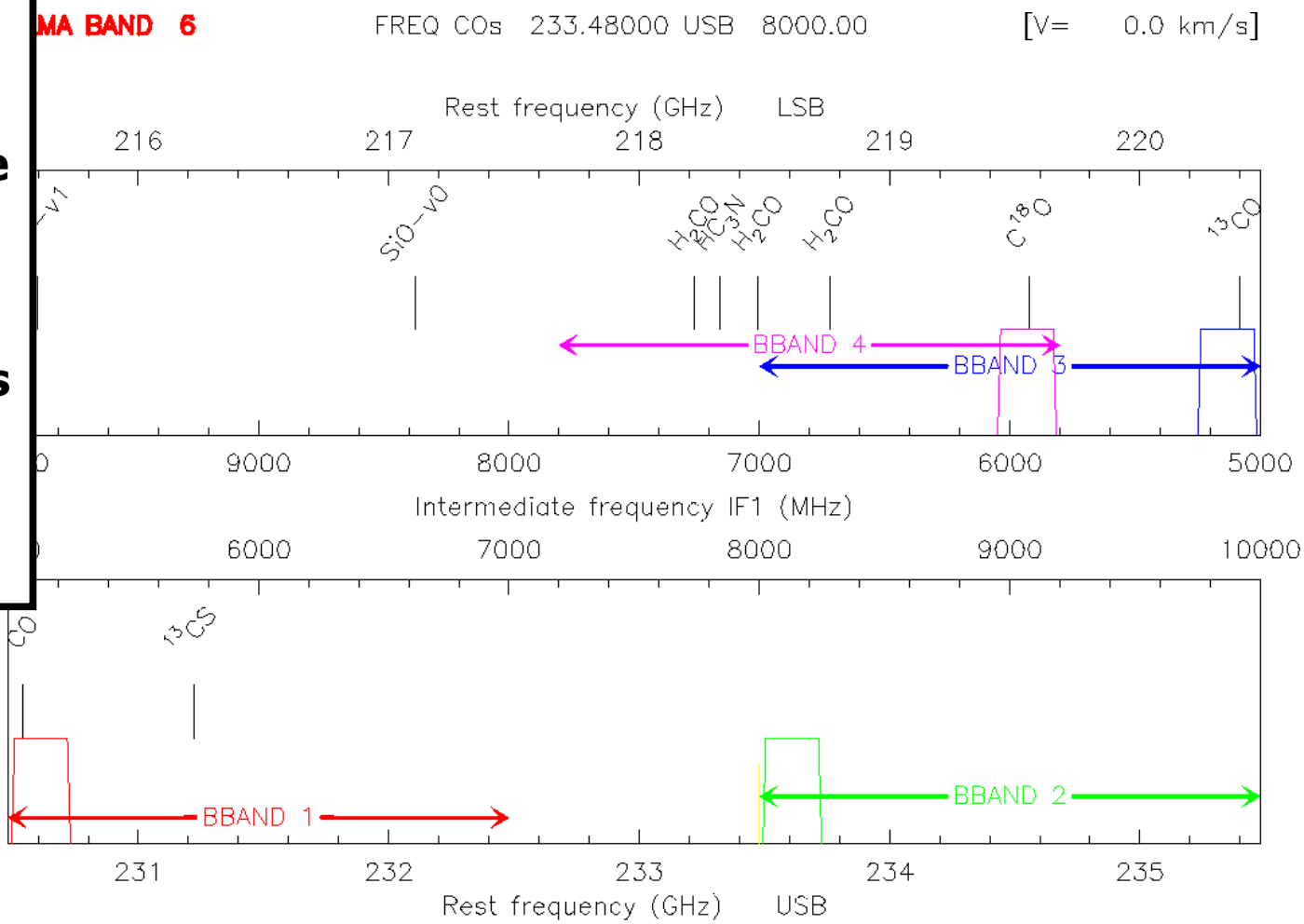
**CAUTION: this is not taken into account by the OT**




**Simultaneous observations of $^{12}$CO, $^{13}$CO and C$^{18}$O (2-1) with B6**

- **$^{12}$CO and $^{13}$CO are near the IF edge**
- **Spectral windows must be strongly offset**
- **Cannot use narrower modes – center would be <50 MHz from edge (forbidden)**
- **Can observe C$^{18}$O**
- **Last baseband has to be in USB (2+2 rule)**

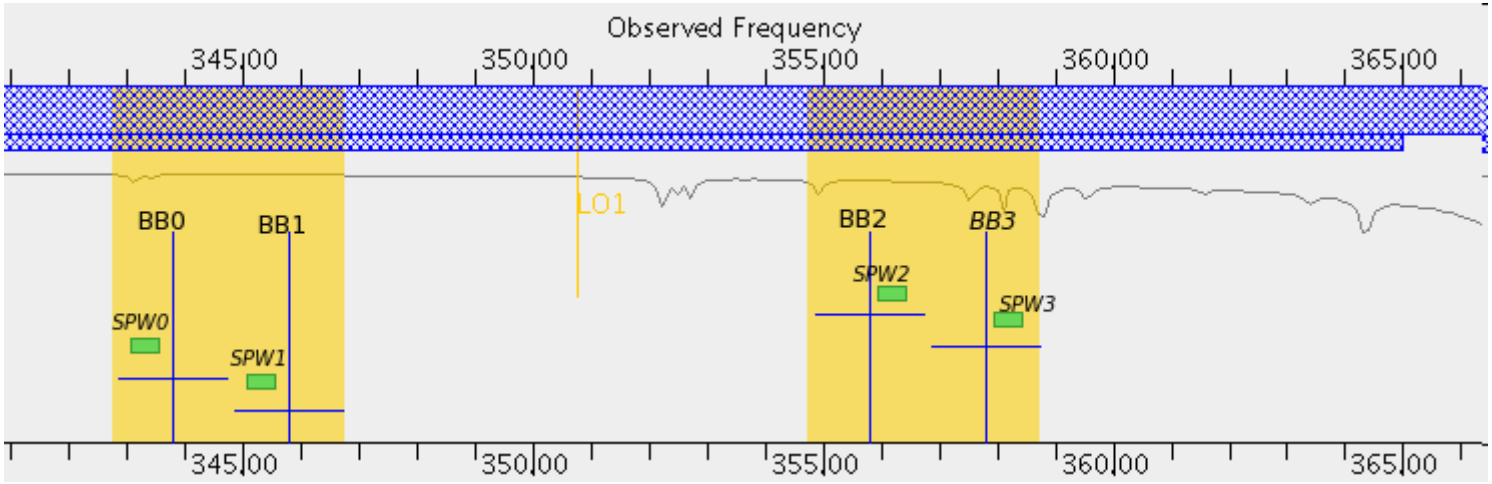
**CAUTION: this is not taken into account by the OT**



# Testing setups with ASTRO

- **GILDAS/ASTRO** can produce Bure-like plots for the ALMA correlator
- The various restrictions are taken into account
- Commands are:
  - **FREQUENCY** to define receiver tuning
  - **BASEBAND** to define position of basebands
  - **PLOT BASE** i to plot baseband i
  - **SPWINDOW** to define spectral window in that baseband
  - **PLOT FREQ** or **PLOT BASE** i to produce updated plots (full view or baseband view)

# Spectral setup in the OT




Yellow areas = LSB/USB (here Band 7)

BB0 to BB3 = 4 basebands, each 2 GHz wide

SPW0 to SPW3 = 4 spectral windows, each within a baseband

Note similar position of SPWs in each baseband

# References

- ALMA Cycle 0 Proposer's Guide
  Doc. 0.2 , V1.1, May 2011

- ALMA Cycle 0 Technical Handbook
  Doc. 0.3, V1.0, May 2011

- ALMA memo 556

- Thanks to A.Baudry (Bordeaux), R.Hills (JAO), R.Lucas (JAO), V.Pietu (IRAM), P.Salome (Paris)