ALMA

EUROPEAN ARC
ALMA Regional Centre || IRAM

iram
Institut de
Radioastronomie
Millimétrique

ALMA Correlator Cycle 1

F.Gueth, IRAM
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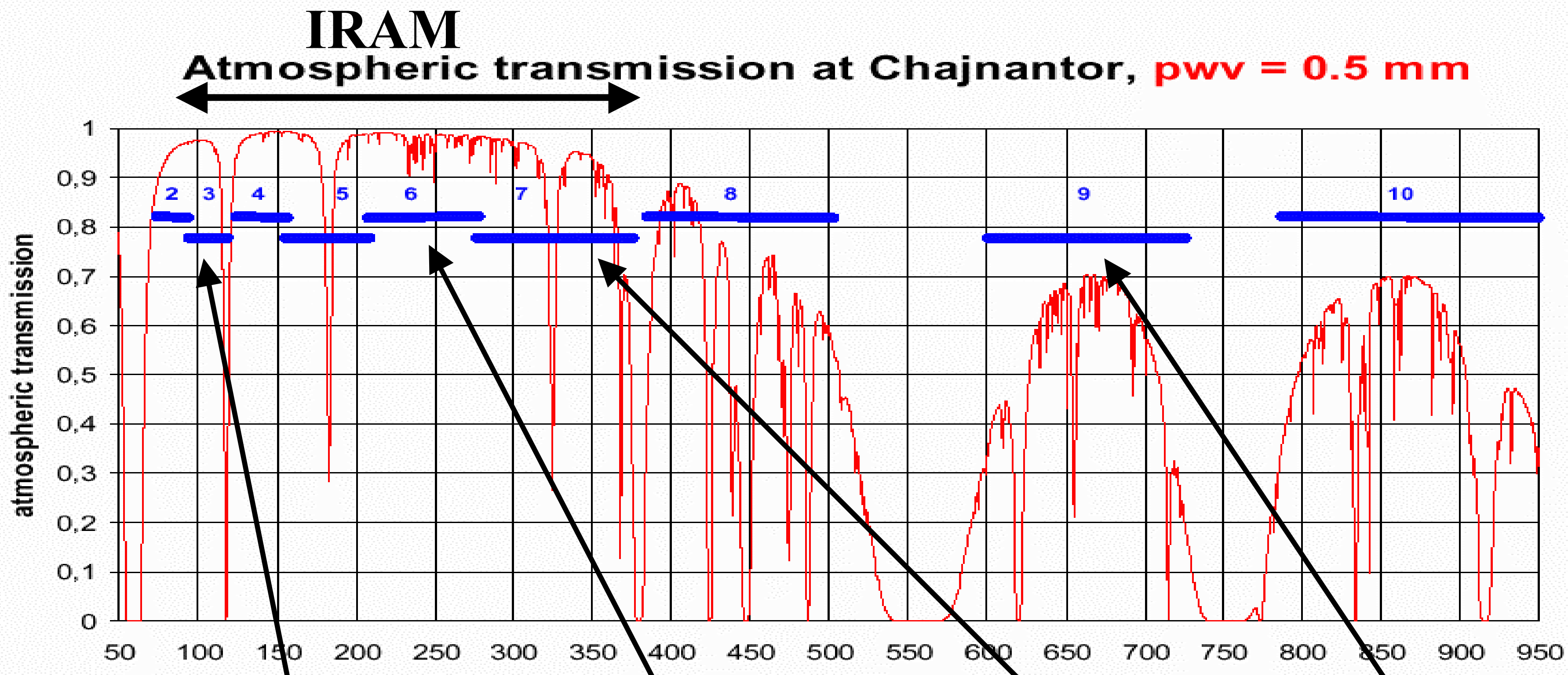
Aim of this document

- This document aims at presenting a user-oriented description of the ALMA correlator modes for Cycle 1
- 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 here.

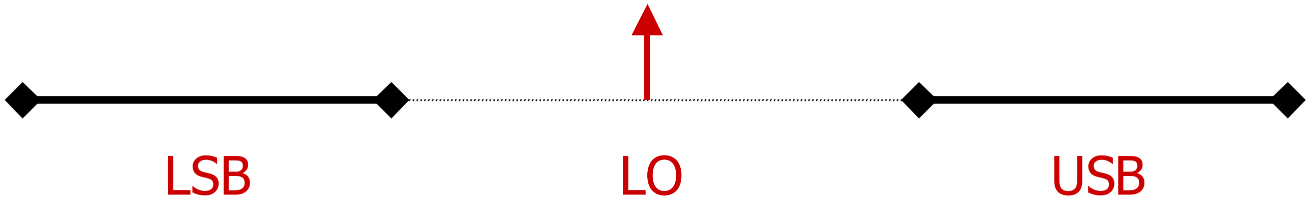
Receiver bands



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

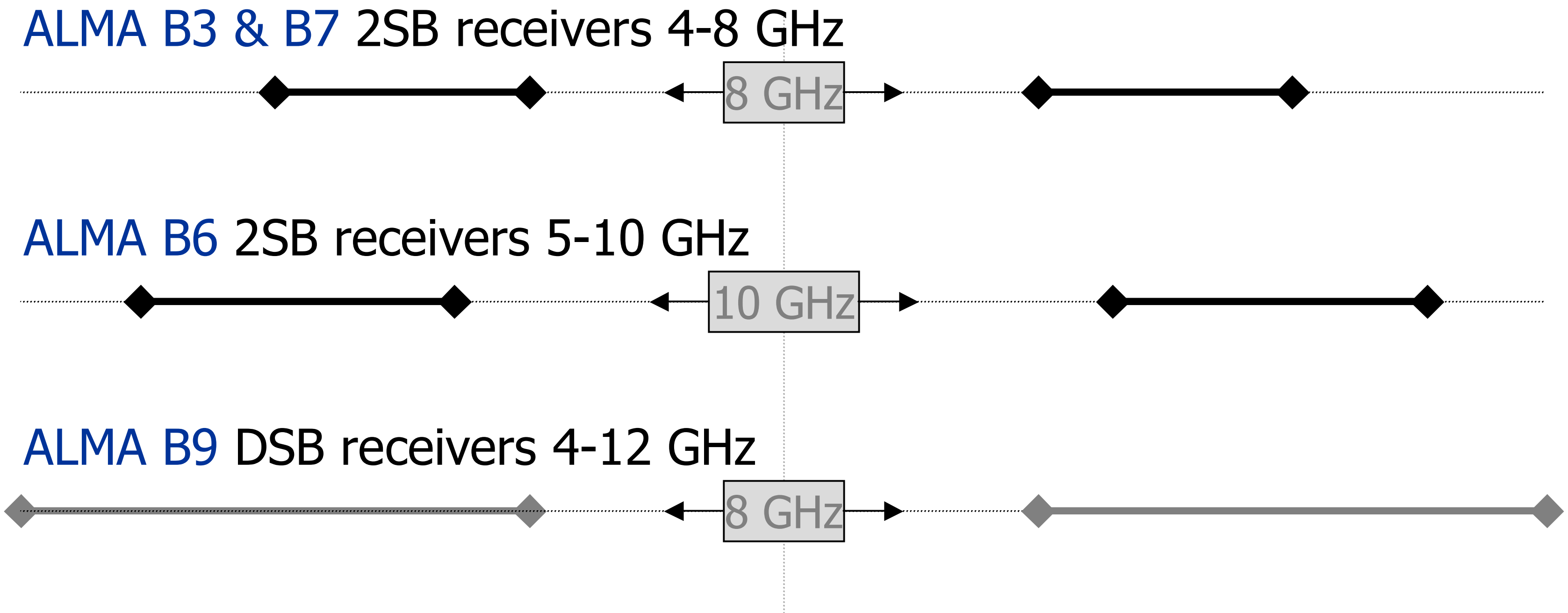
ALMA B6 2SB receivers 5-10 GHz

ALMA B9 DSB receivers 4-12 GHz

Receivers have bands 8 or 10 GHz bandwidth

x 2 polarizations

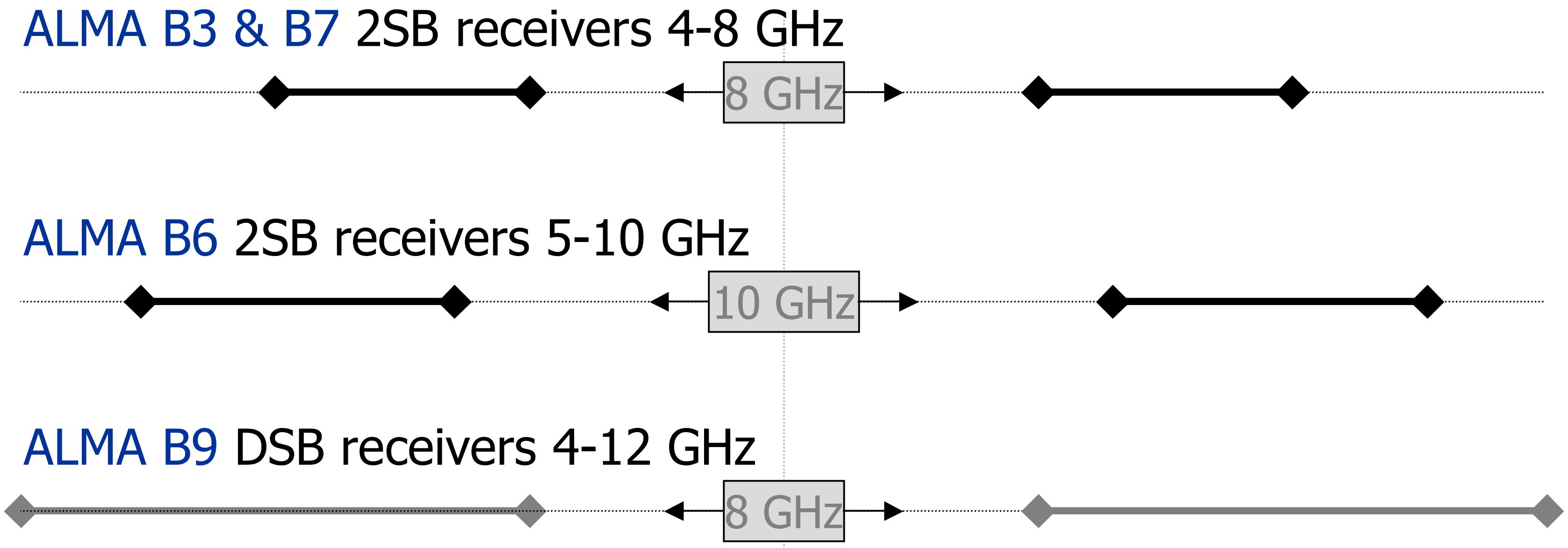
ALMA receivers



B6 receivers have 10 GHz bandwidth – but <u>only 8 GHz can be processed</u> by the IF and correlator system

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

ALMA receivers



B9 are double sideband receivers – in Cycle 1, 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**

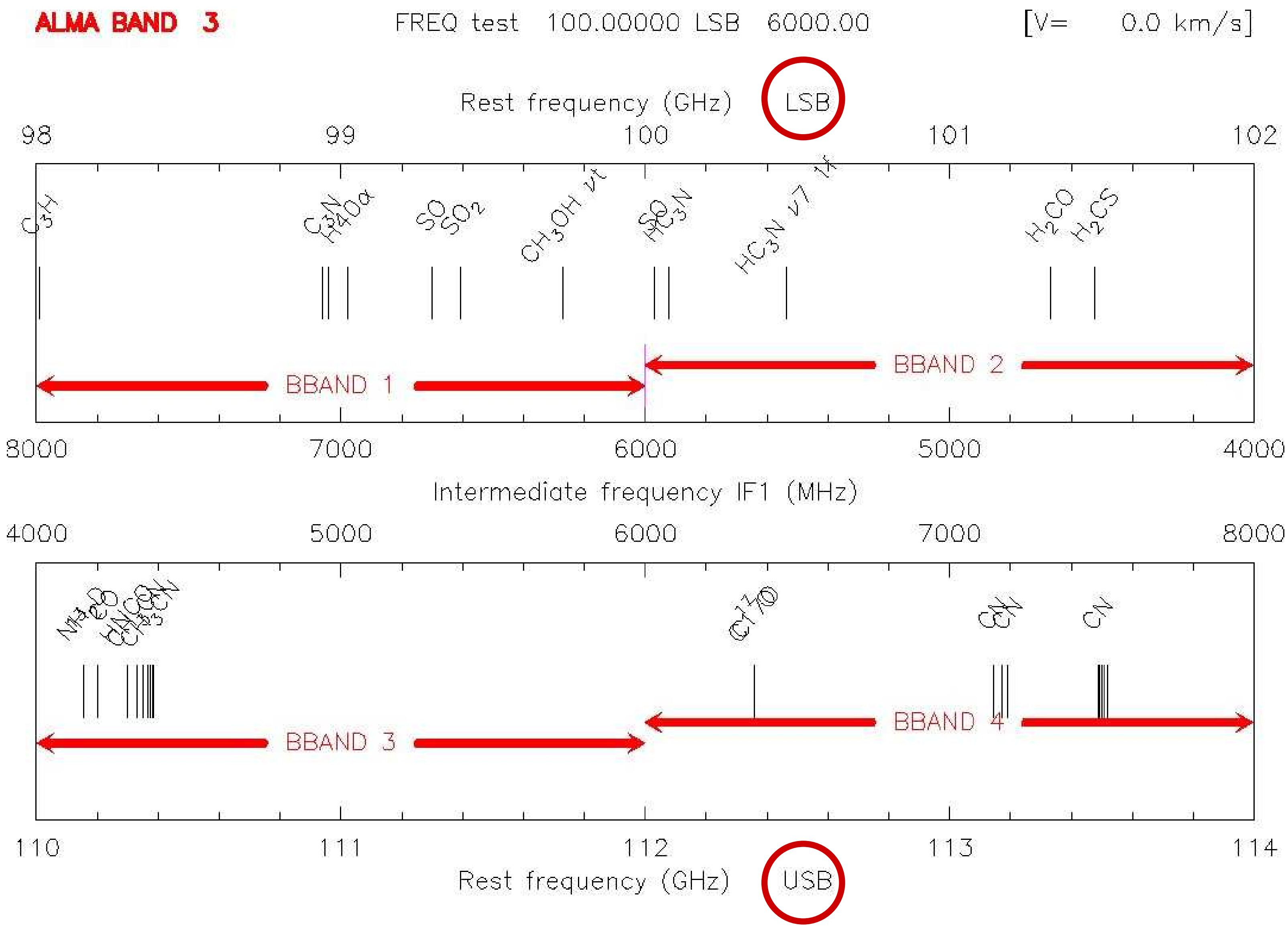
Can process incoming 8 GHz x 2 polarizations

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

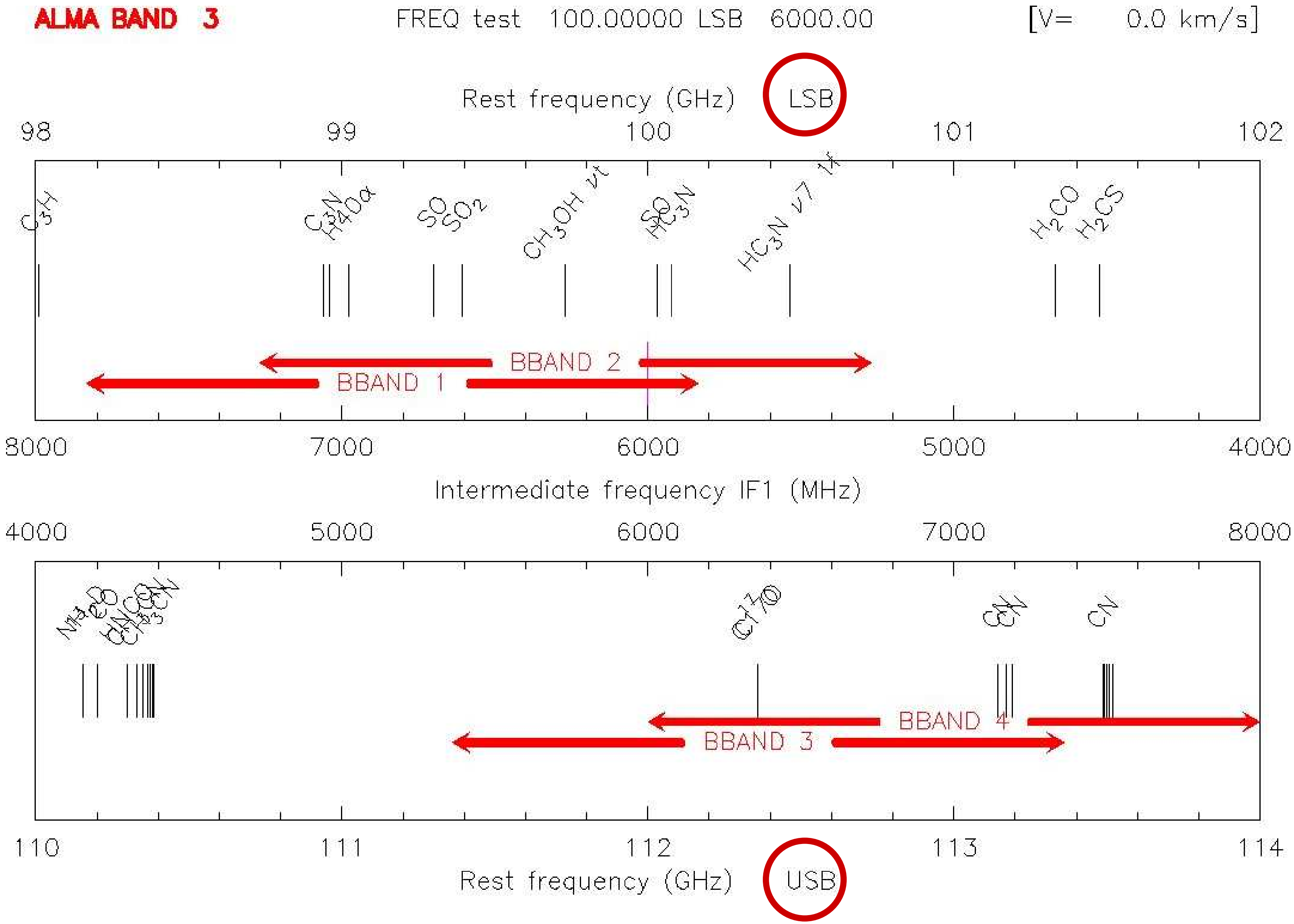
(* Minor limitations because of LOs finite step)

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

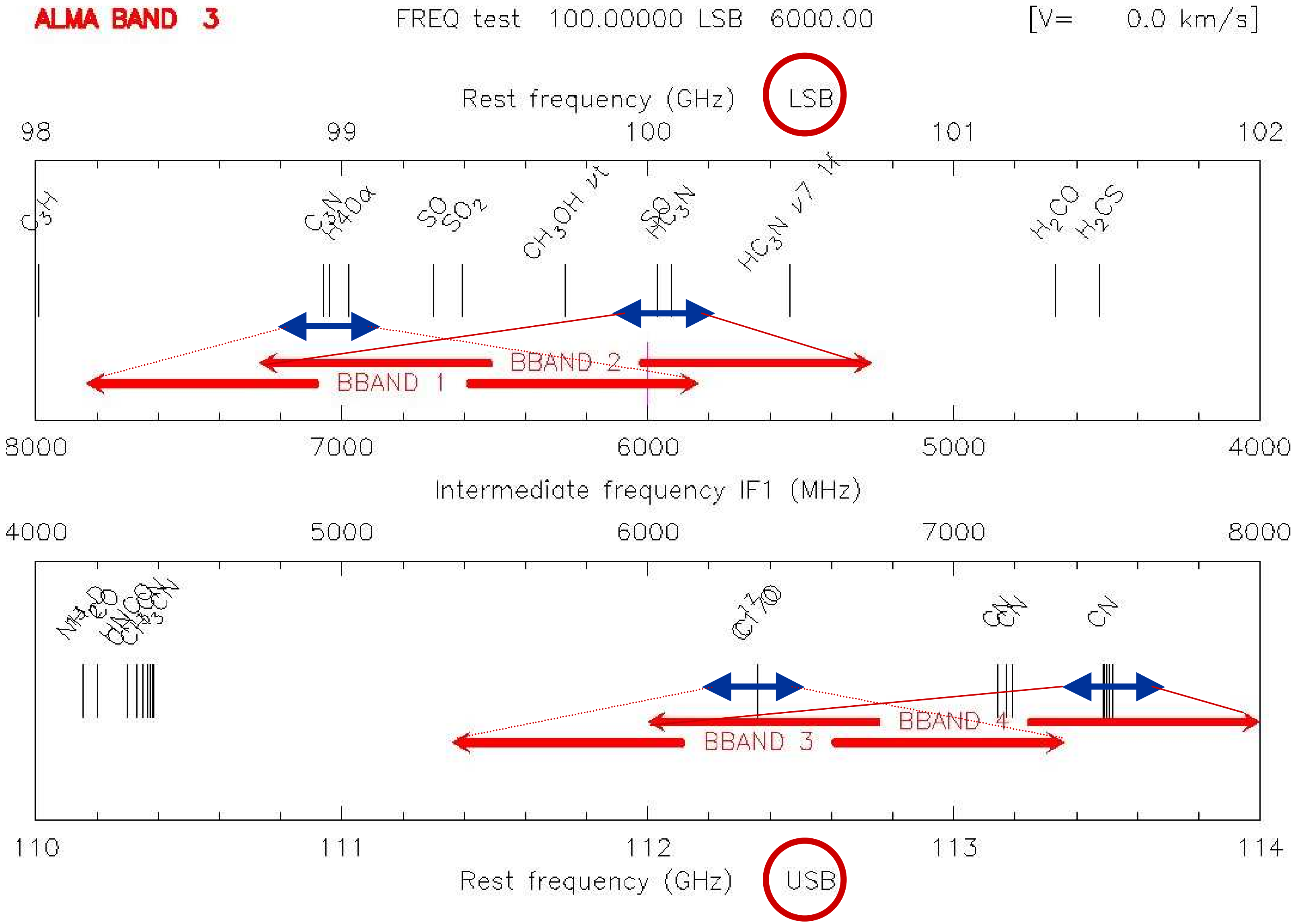
Four basebands covering the 8 GHz



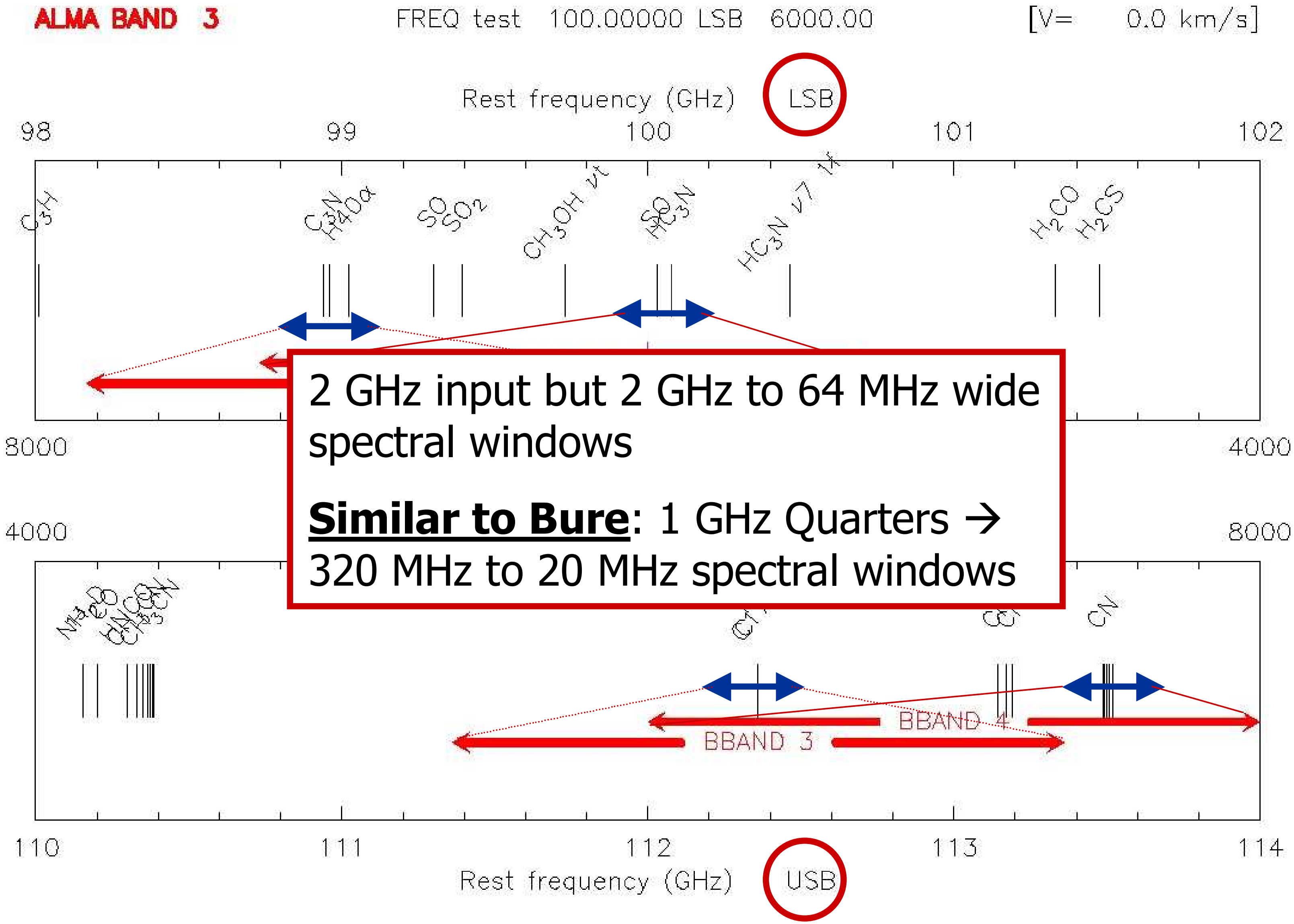
Four overlapping basebands



Four overlapping basebands (red) giving four distinct spectral windows (blue)



Four overlapping basebands (red) giving four distinct spectral windows (blue)



2 GHz input but 2 GHz to 64 MHz wide spectral windows

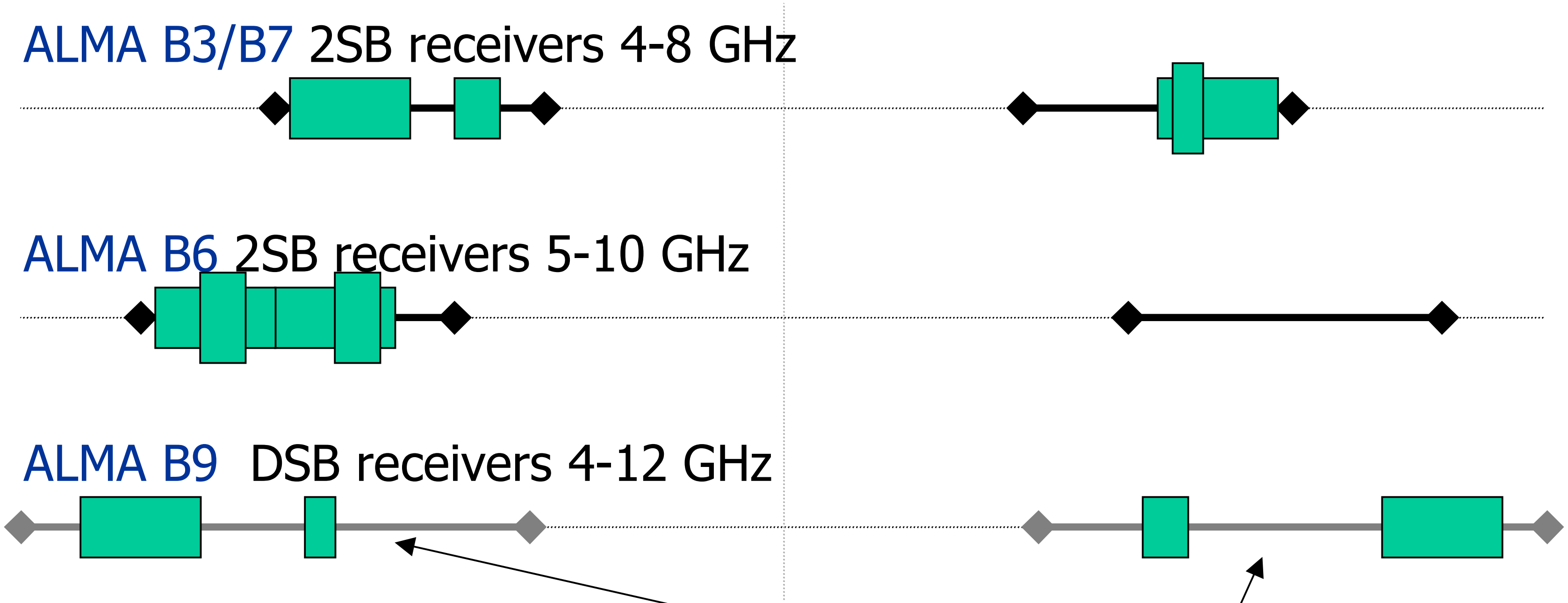
Similar to Bure: 1 GHz Quarters → 320 MHz to 20 MHz spectral windows

Example

Four basebands covering 8 GHz

Note B6 larger bandwidth (2x5 GHz)

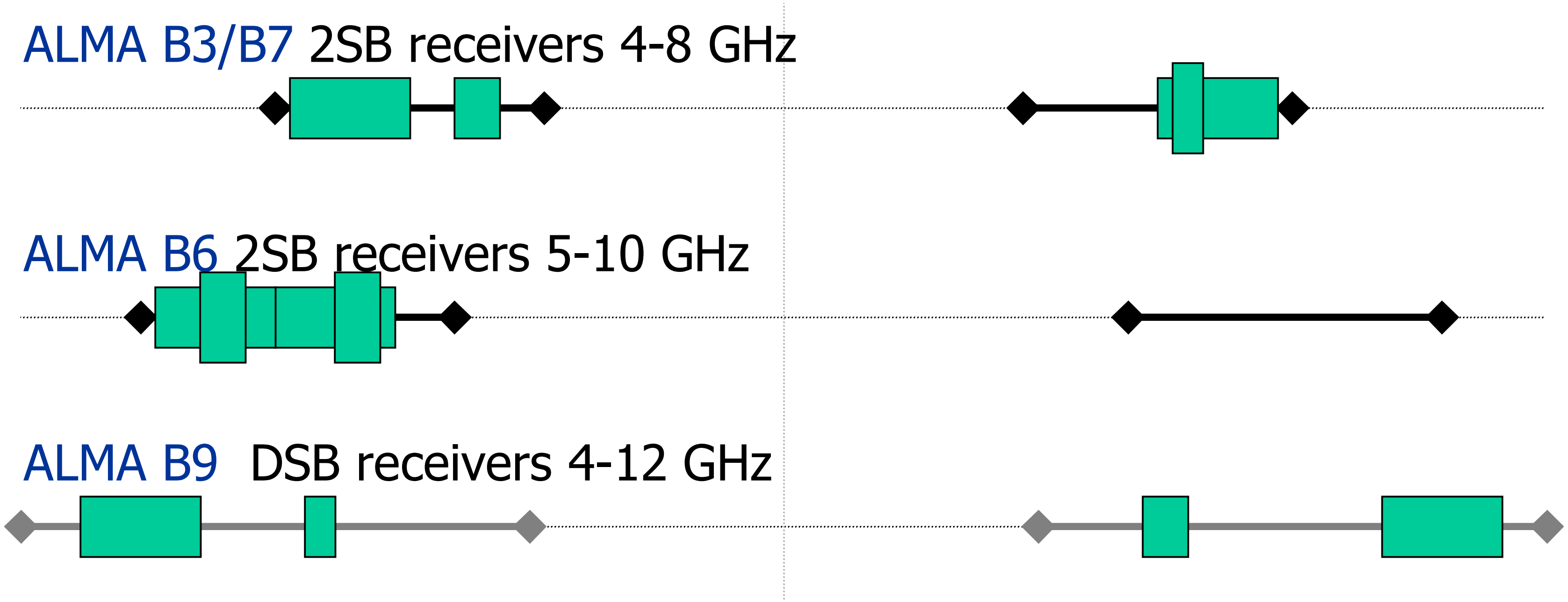
Example



Four basebands with different width/resolution

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

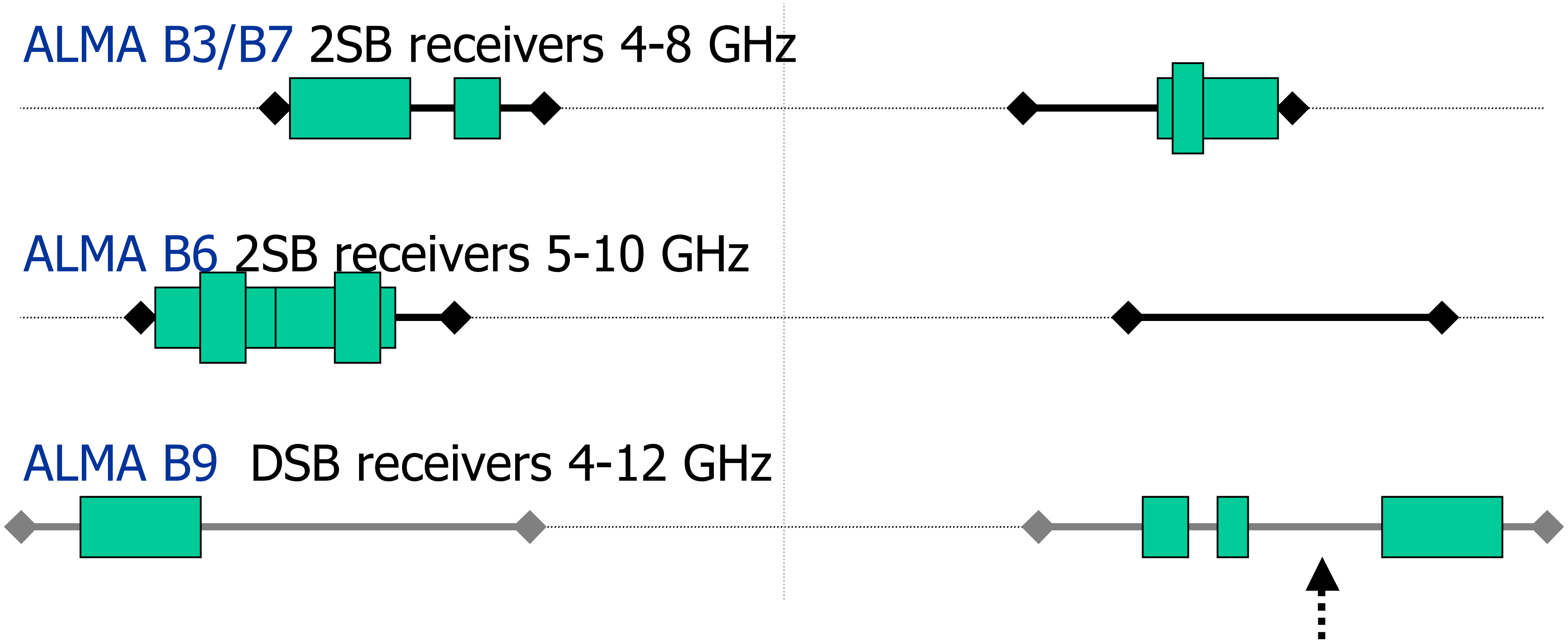
Example



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

<u>1 polarization output (H or V)</u>

- 2 GHz 8192 channels x 1 Pol x 244 kHz spacing
- 1 x 122 kHz spacing
- 50 x 61 kHz spacing
- 25 x 30 kHz spacing
- 12 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

<u>4 polarization outputs (HH, VV, HV and V</u>[illegible]

- 2 GHz 2048 channels x 2 [illegible] pacing
- 1 GHz 2048 chann [illegible] kHz spacing
- 500 MHz 2048 [illegible] 244 kHz spacing
- 250 MHz 2 [illegible] Pol = 122 kHz spacing
  125 M [illegible] s x 4 Pol = 61 kHz spacing
- 6 [illegible] annels x 4 Pol = 30 kHz spacing

- 2 [illegible] 64 ch. x 4 Pol = 31 MHz spacing

NOT OFFERED IN CYCLE 1

Number of channels = 8192/Npolar

Real bandwidths

FDM modes

- Bandwidth edges are not used to avoid aliasing & edge effects
- **Effective bandwidth is 15/16th of the nominal width**
- **Actual 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)
- All channels are written in the data, they must be dropped off-line

Real bandwidths

FDM modes

- Bandwidth edges are not used to avoid aliasing & edge effects
- **Effecti**
- **Actual** ... **192** (remai ... not written

TDM mo

- Filter ir
- FDM lar
- TDM: limits usable **bandwidth of continuum mode to 1875 MHz** (instead of 2000 MHz)
- All channels are written in the data, they must be dropped off-line

<u>Consequences: continuum sensitivity</u>

- Both in FDM and TDM, the maximal bandwidth available is 1875 MHz per baseband
- Maximal bandwidth for continuum is 4x1.875 = **7.5 GHz** (per polarization)
- This is taken into account by the OT

Correlator Cycle 1

Proposers guide p.33

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.33

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

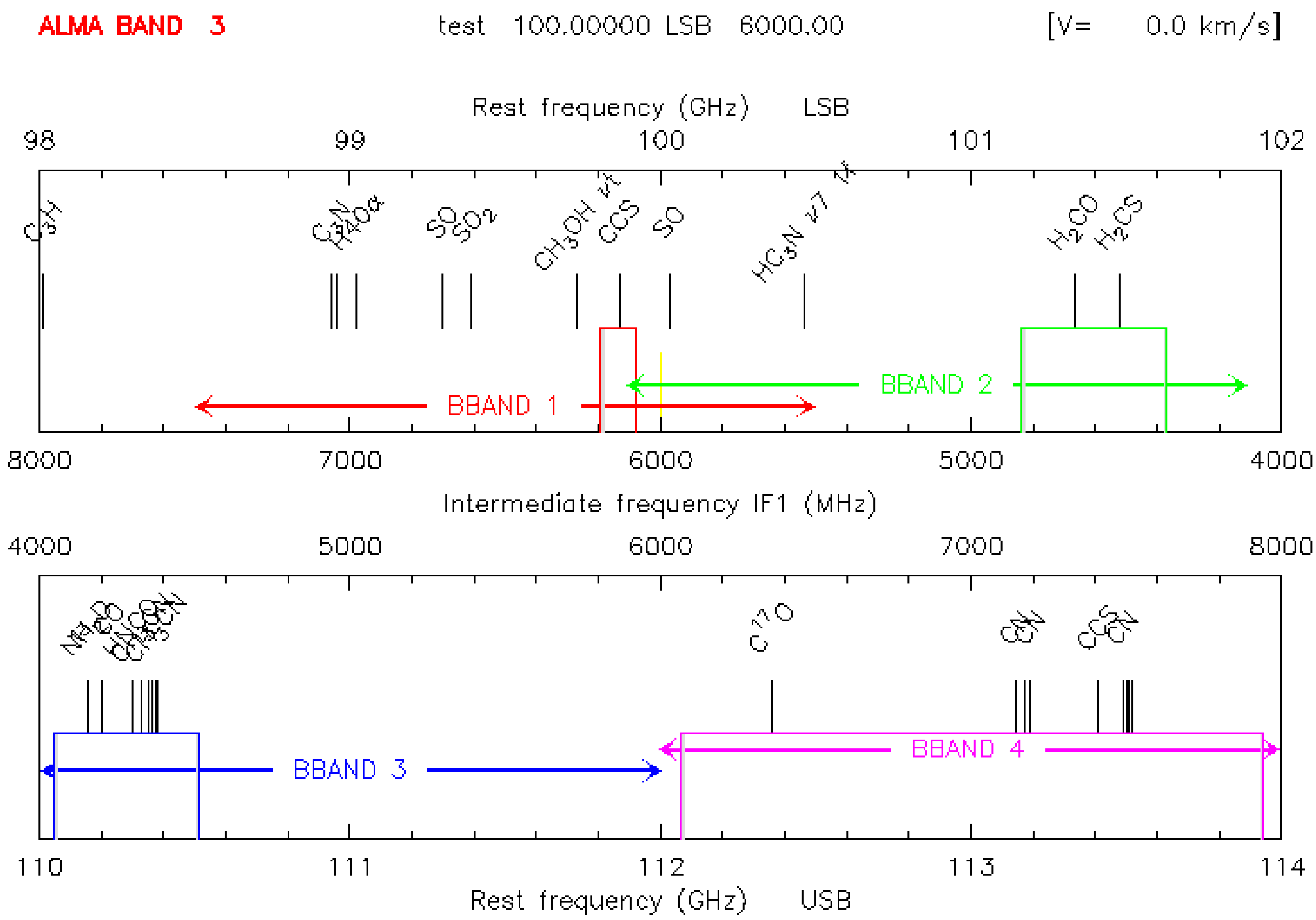
- Continuum mode 128 ch. x 2 Pol = 15.6 MHz resol.

TDM

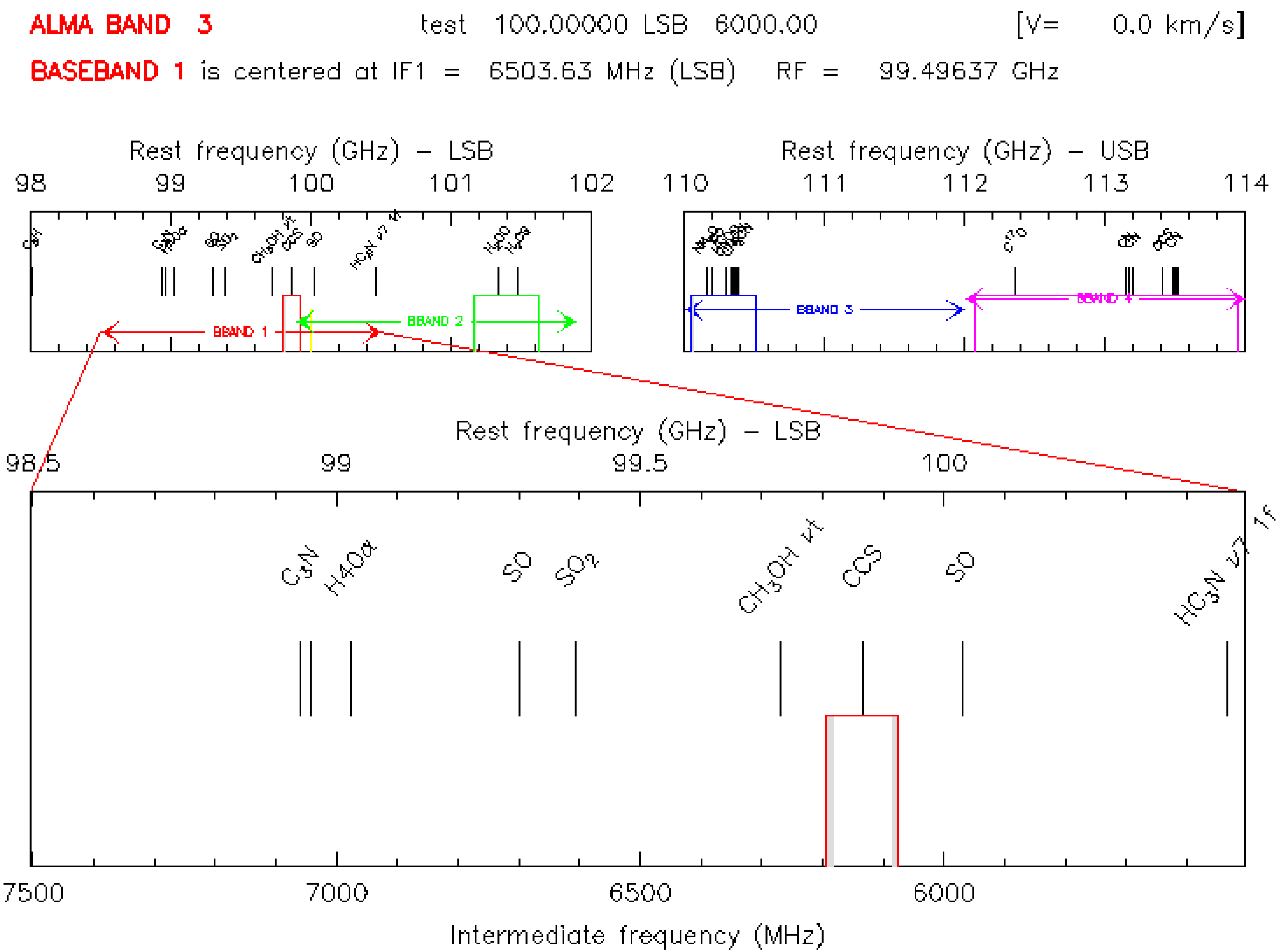
Cycle 0 vs. Cycle 1

In Cycle 0, all four spectral windows had to share the same mode (resolution, bandwidth, position within the baseband)

In Cycle 1, the four spectral windows are independent



Example : 4 independent spectral windows (one per baseband)



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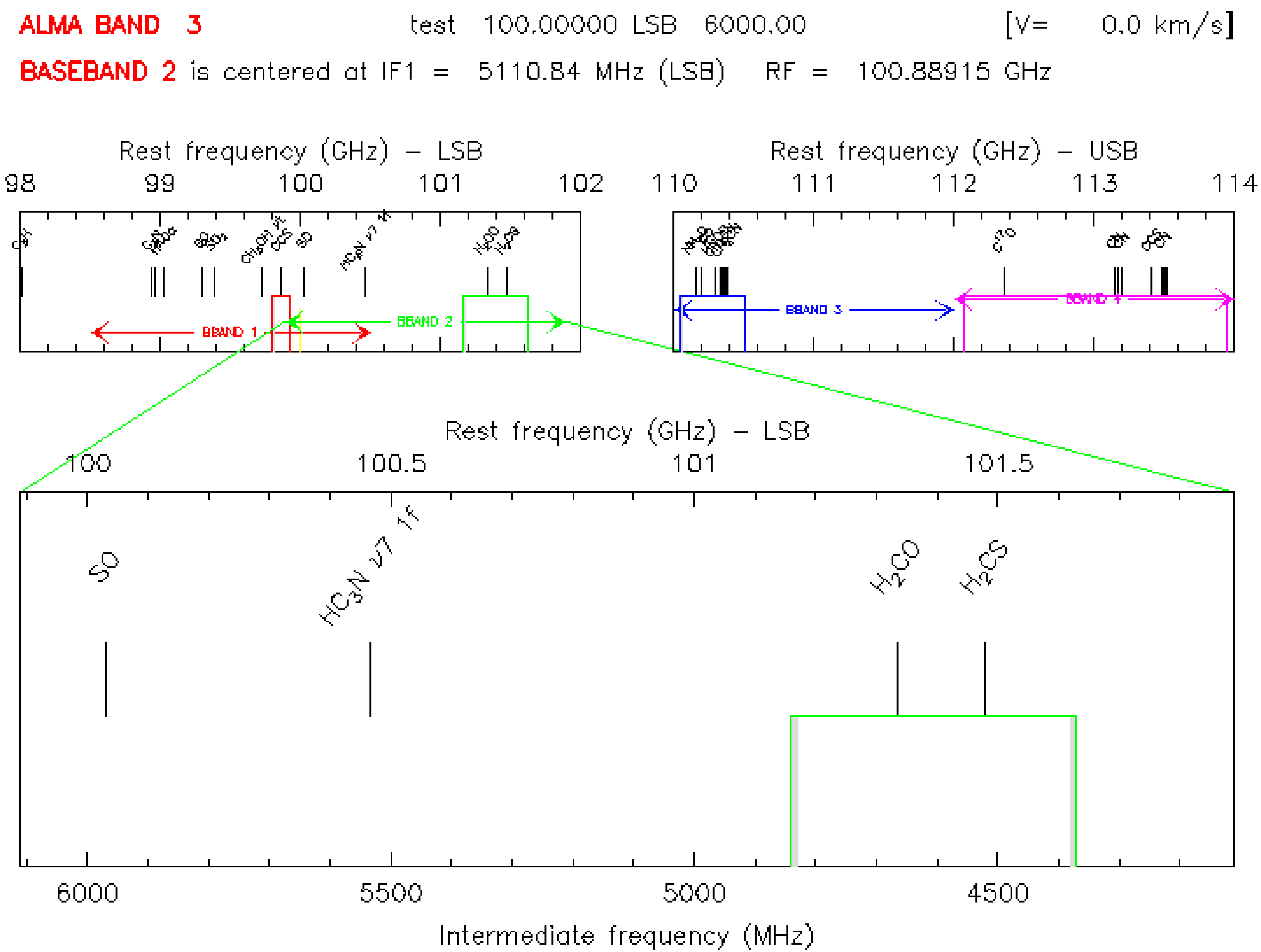

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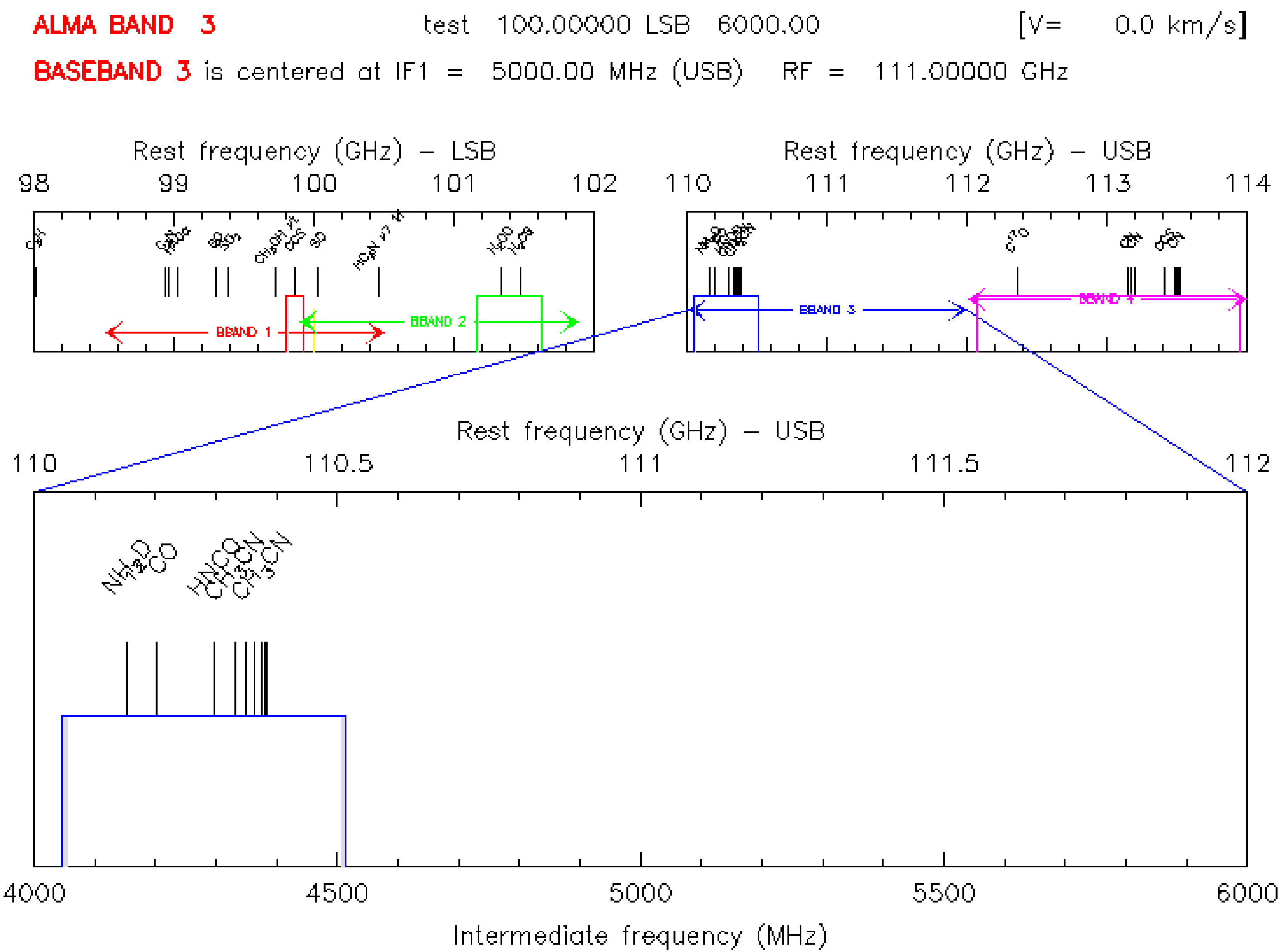

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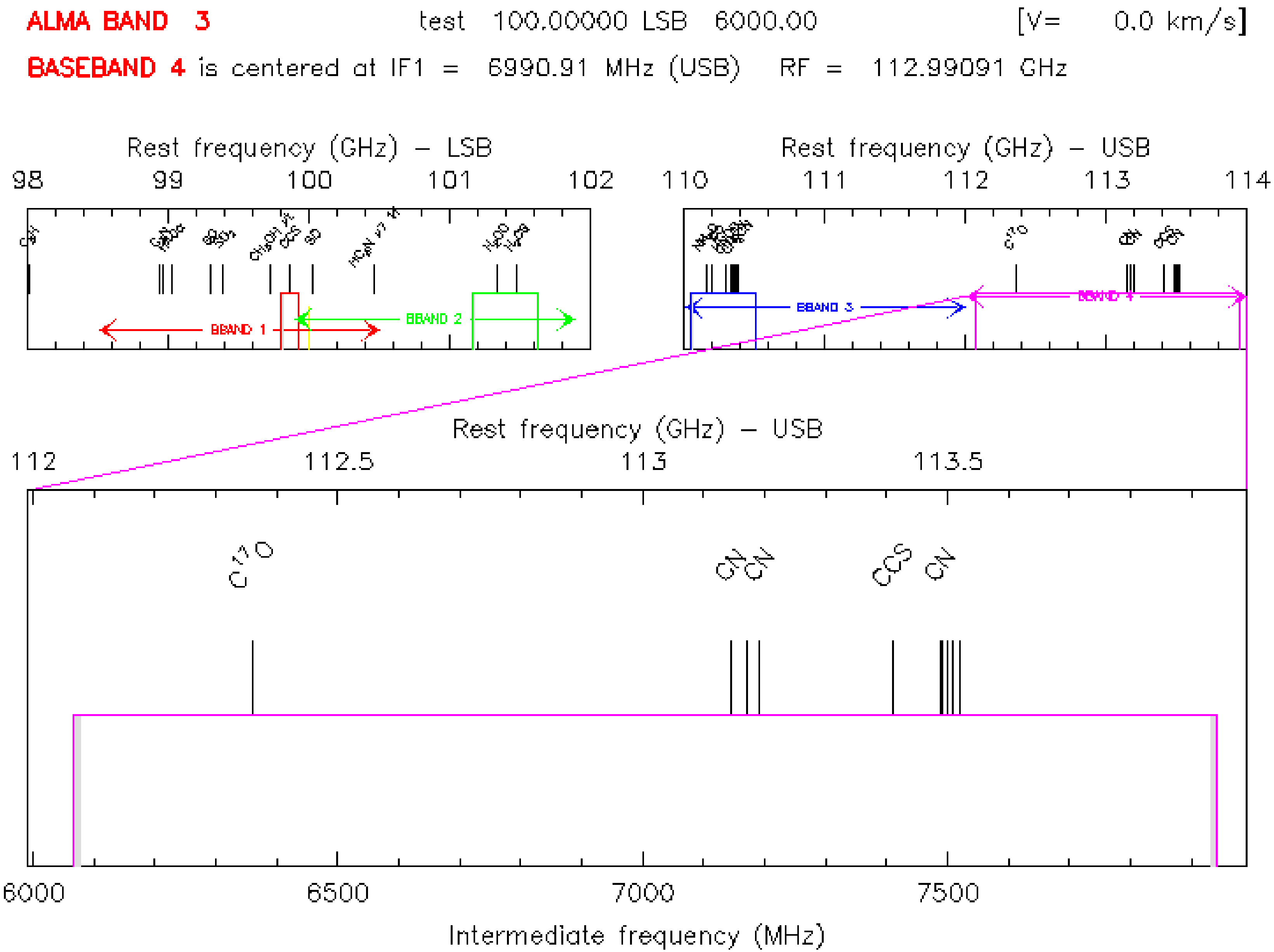

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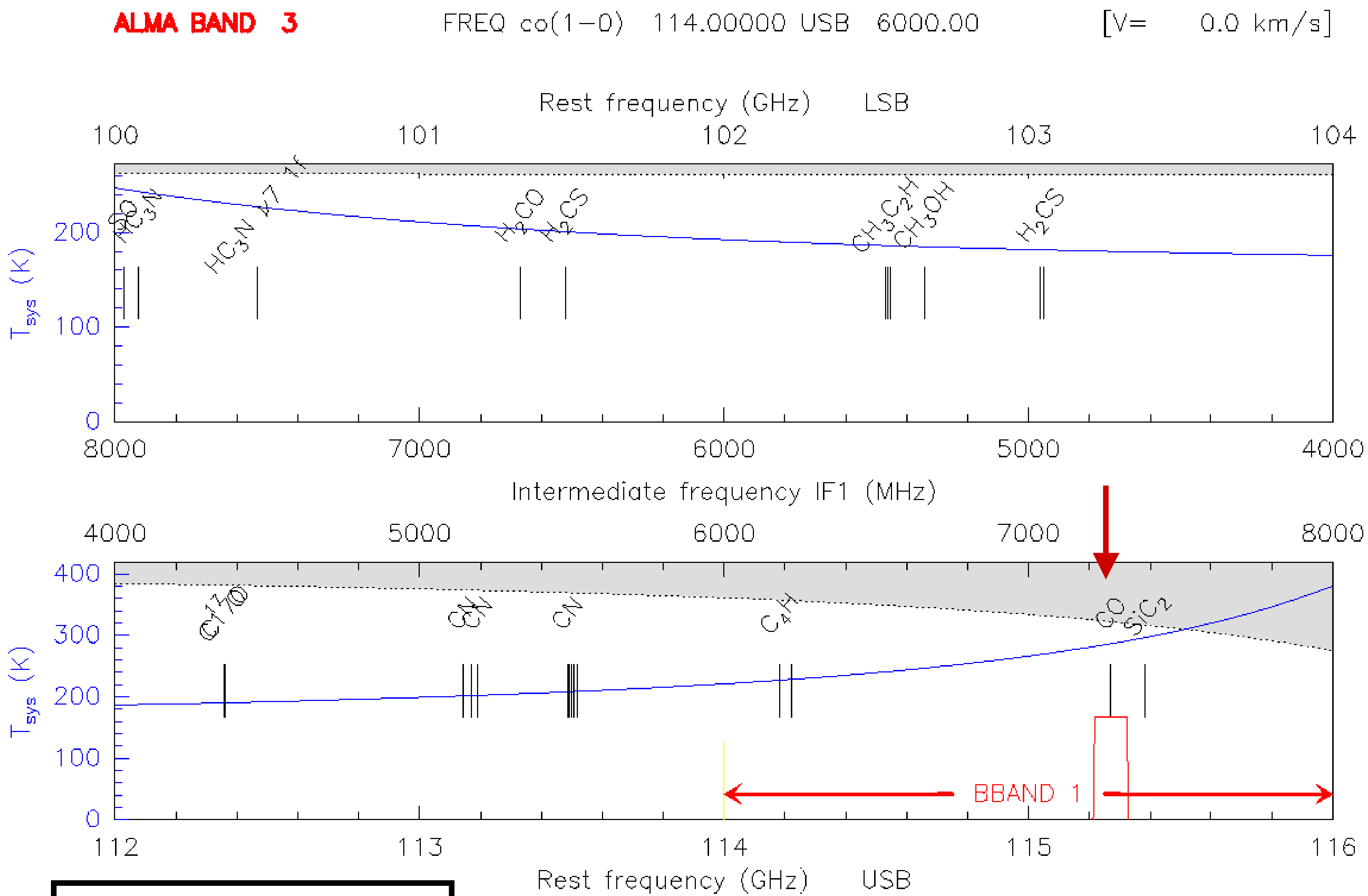
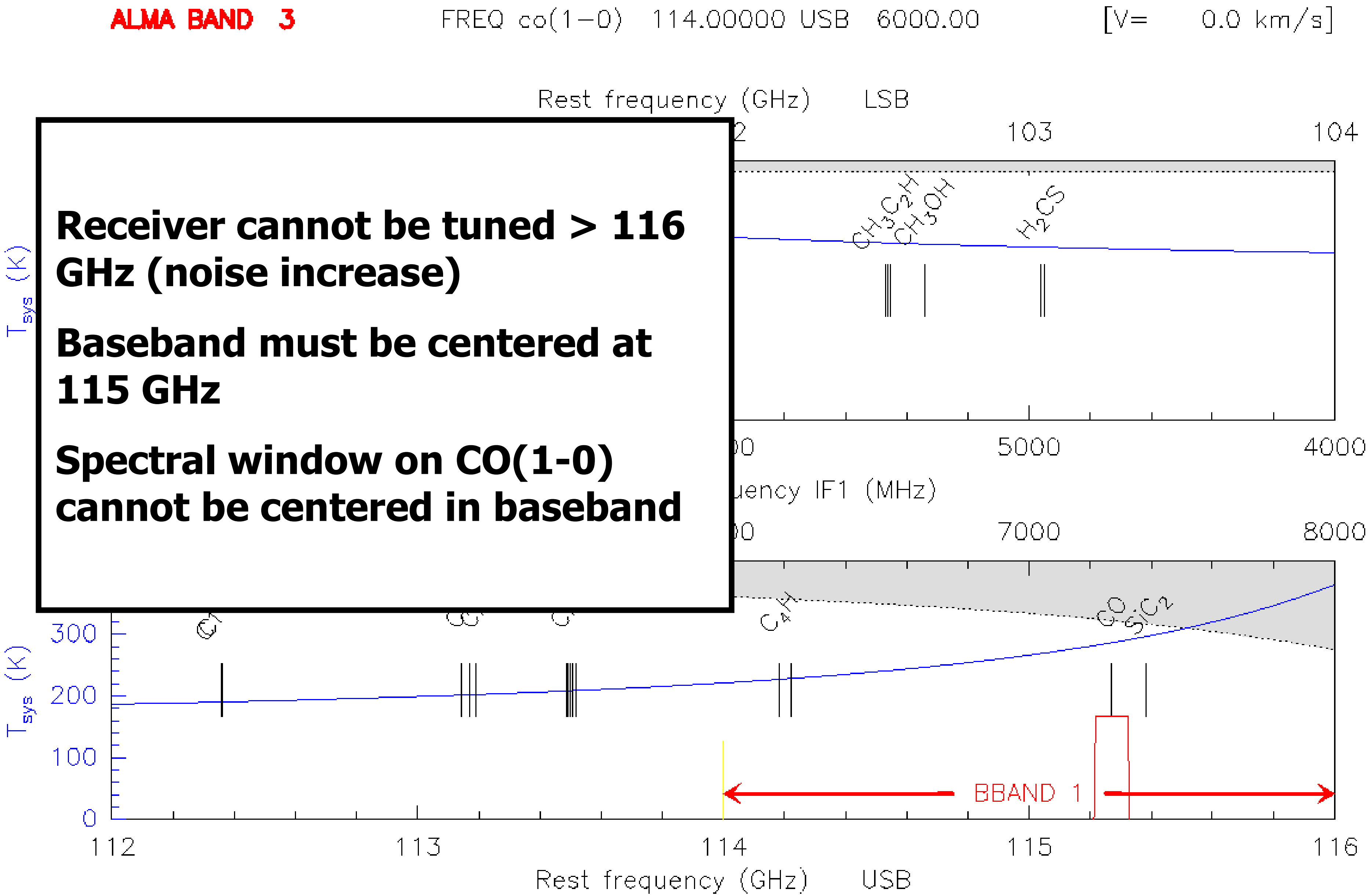


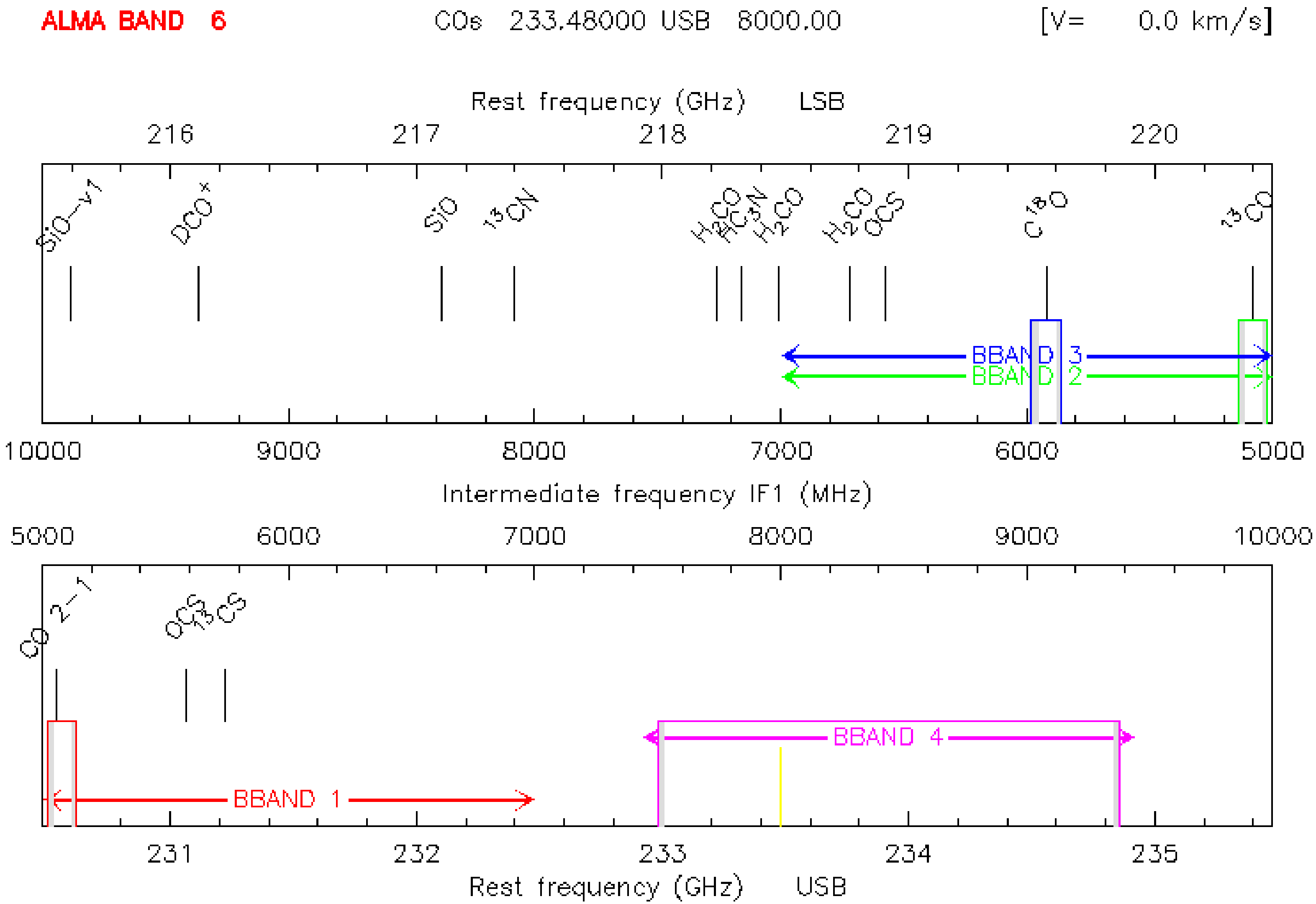
^{12}CO (1-0) with B3



Receiver cannot be tuned > 116 GHz (noise increase)

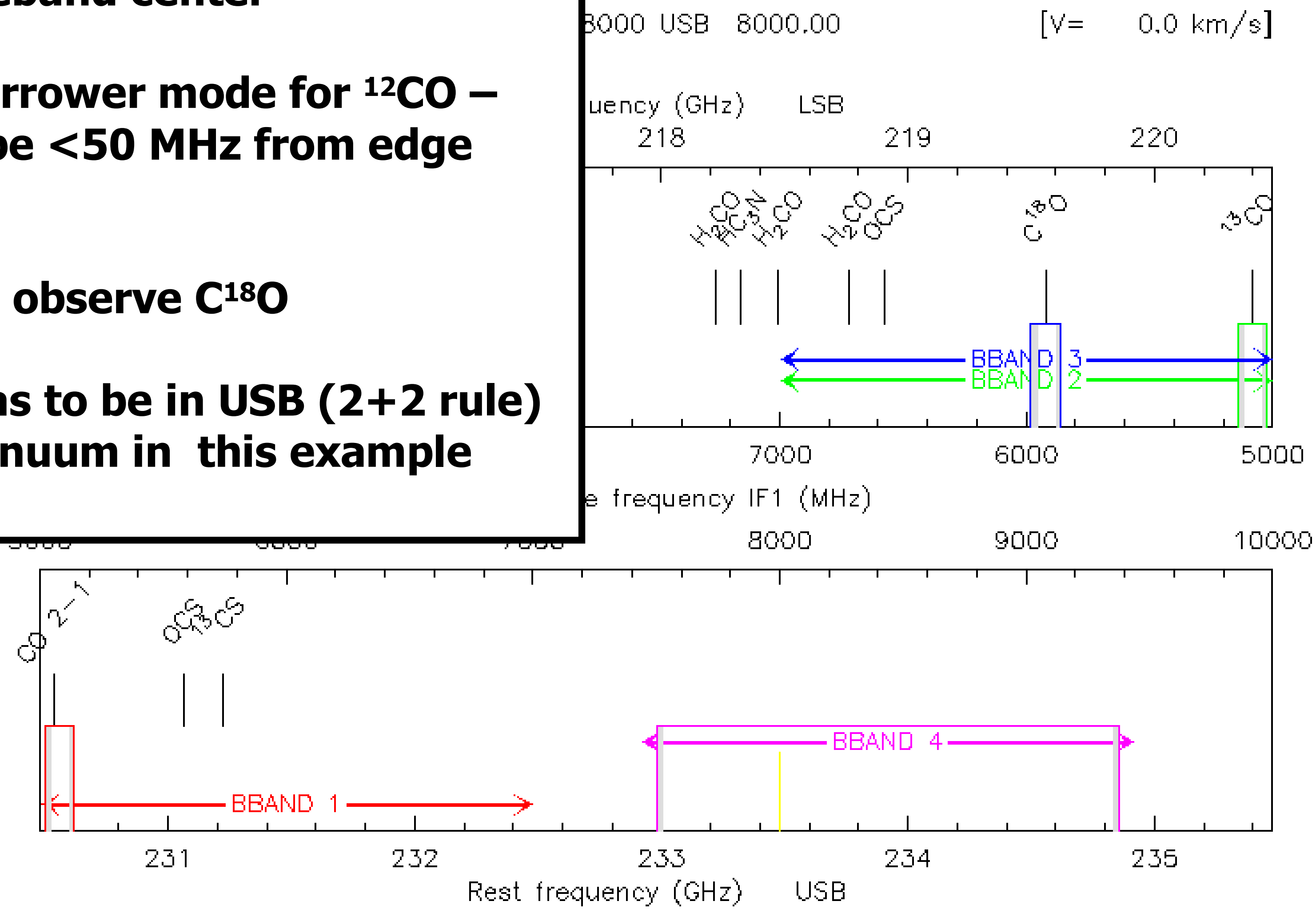
Baseband must be centered at 115 GHz

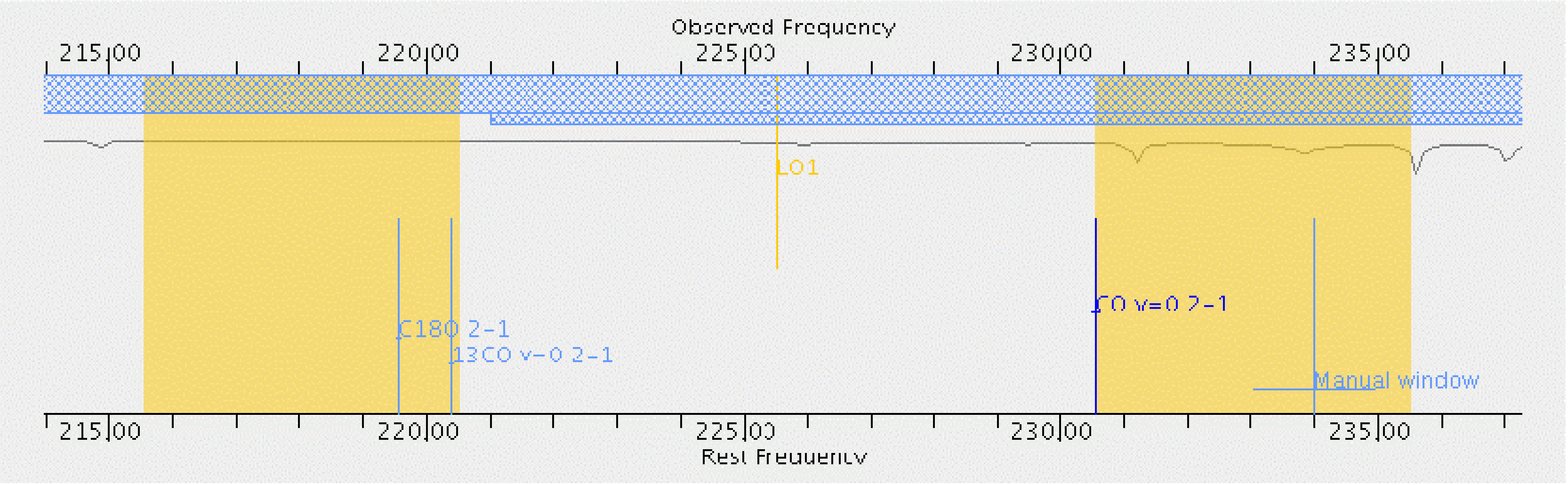
Spectral window on CO(1-0) cannot be centered in baseband



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 wrt baseband center
- Cannot use narrower mode for ^{12}CO – center would be <50 MHz from edge (forbidden)
- Baseband 3 to observe $C^{18}O$
- Baseband 4 has to be in USB (2+2 rule) – used for continuum in this example





Spectral setup display in the OT:

Yellow areas = LSB/USB (here Band 7)

Vertical line = center of each spectral window

Horizontal line = width of each spectral window

Testing setups with ASTRO

- **GILDAS/ASTRO** can produce Bure-like plots for the ALMA correlator
- The various restrictions are taken into account

- Commands are:
  - **SELECT cycle 0|1|full** to select the ALMA cycle
  - **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)

References

- G.Mathys, 2012, ALMA Cycle 1 Proposer's Guide, Version 1.0.2 , ALMA, May 2012

- A.Lundgren, 2012, ALMA Cycle 1 Technical Handbook, Version 1.0, ALMA, May 2012

- ALMA memo 556

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