Study of the calibration channel width for a Digital Sideband Separating system for SIS 2SB receivers

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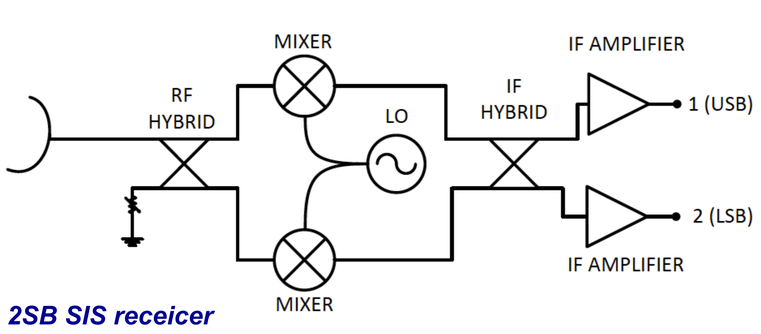
Abstract

•Digital Sideband Separating (DSS):
- Very promising concept for future (multipixel) heterodyne receivers.
- Relaxes requirements for the Image Rejection Ratio (IRR) of analog receivers.
- It improves the IRR substantially with simple hardware.
- Ideal for spectral line surveys (it practically eliminates line confusion and atmospheric noise in the image band).
- It is a potential option for a future ALMA upgrade.

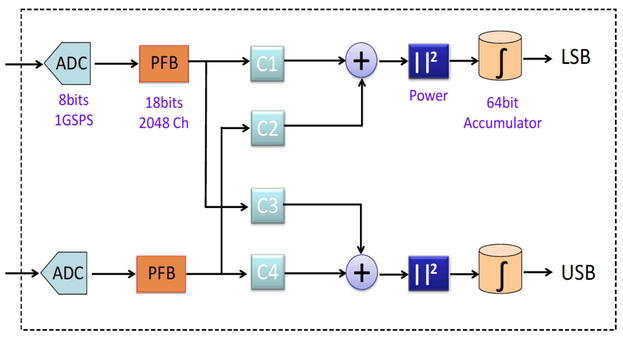
•Recent work:
- Applied to a full 2SB receiver (i.e. including the analog IF hybrid).
- It allows reaching an IRR of 45 dB across the full band.
- Calibration is more stable respect to the case without IF hybrid.

•Important question:
- How wide should the calibration-channel width be in order to reach a desired IRR level?
- It determines, for a large part, the calibration speed of the DSS system and influences the back-end architecture.

Concept of Digital Sideband Separating System



2SB SIS receicer

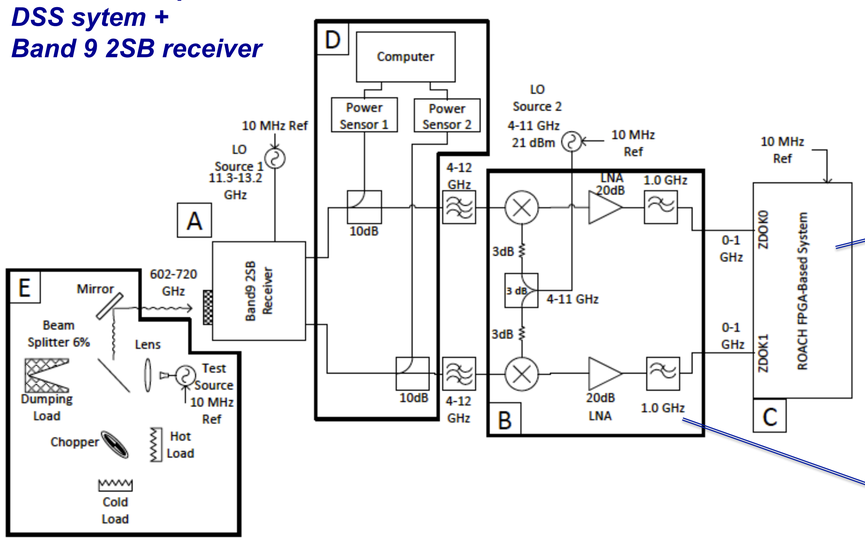


Sideband ratio correction scheme

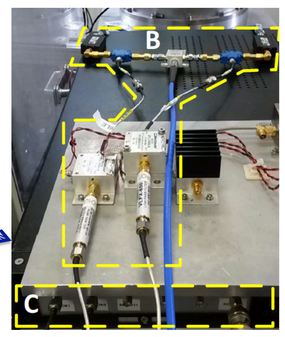
The DSS system can be used either as:
- An adaptive IF hybrid to reach ultra-pure image rejection [Finger et al. A&A 2015]
- It can be applied to a full 2SB receiver for IRR correction [Rodriguez et al. A&A 2018].
- The latest option has advantages in stability and in possibility to be applied directly to existing instruments.

Implementation for ALMA Band-9 2SB receiver

Scheme of experiment:
DSS sytem +
Band 9 2SB receiver

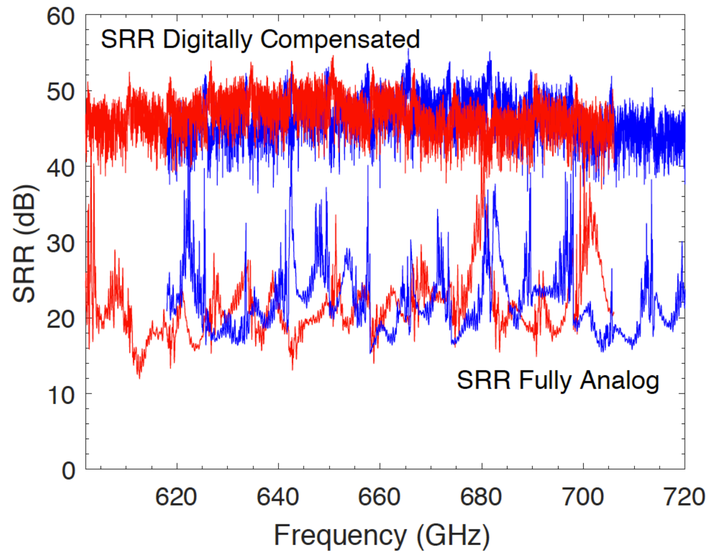


FPGA processing board



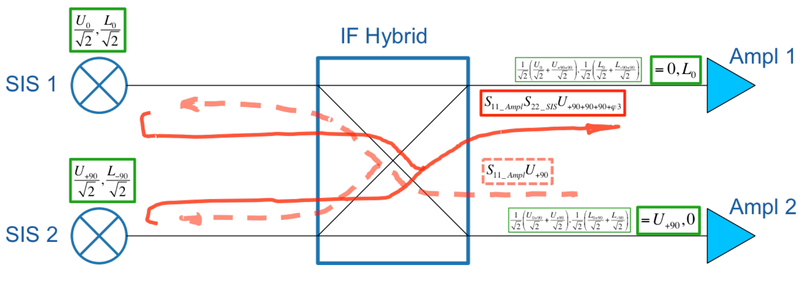
Second down-conversion stage

Scheme: **A** – 2SB SIS receiver for Band 9, **B** - second down conversion stage, **C** – digital back-end, **D** – set to measure calibration stability, **E** – optical scheme for injection of the test tone. Results will be published in A&A (paper was accepted in Dec 2017).

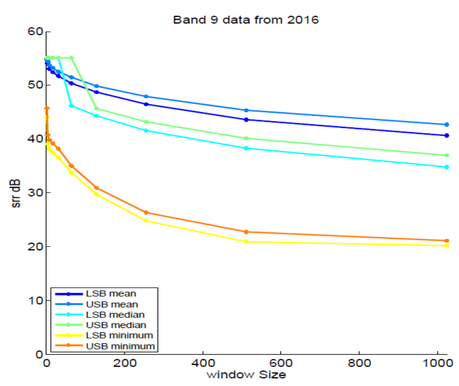


The digitally compensated IRR is above 40 dB.
Digital Polarization Synthesis using similar approach has been demonstrated [].

Width of calibration channel to reach certain IRR level

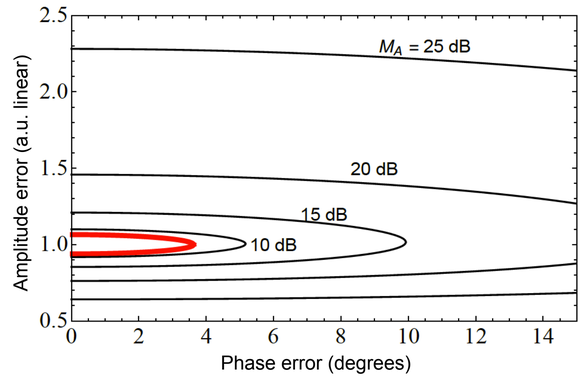


Mechanism of the main contribution to imbalance:
Reflection from Amplifiers and SIS mixers trough the Hybrid {Ampl←→SIS} :
Imbalance amplitude $S_{22\_SIS} \cdot S_{H\_ISO}$ = *(-5dB)+(-10..-20dB) = -15..-25dB*,
periodic – determined by the cable length between SIS and amplifier (isolator).



Analysis of measured data: calibration channel can be 244kHz x 64 = 15.6 MHz

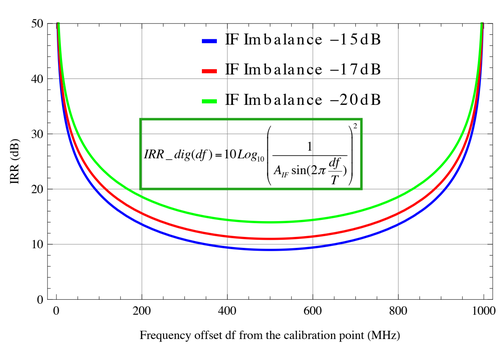
Advantage compared to receiver without the IF hybrid



Error zones, providing 30 dB IRR level: red line - system without IF hybrid, black lines - full 2SB receiver with different level of analogue IRR. Error is injected between the receiver and the FPGA board.

IRR level	Band 3	Band 4	Band 5	Band 6 (???)	Band 7	Band 8	Band 9 no Isolators	Band 9 with Isolators
Cable length (mm)	200	350	100	200	200(?)	250	400	300
Reflection period (MHz)	500	285	1000	500	500(?)	400	250	330
SIS mixer S22, (dB)	5(?)	5(?)	5(?)	15(?) - amplifier 1	5(?)	5(?)	5(?)	5(?)
S11 of Isolator (or amplifier) (dB)	18	19	19	18	18	19	10	18
dF for IRR of **30 dB** (MHz)	**33**	**23**	**80**	**33**	**33**	**32**	**7**	**22**
dF for IRR of **20 dB** (MHz)	**110**	**77**	**270**	**110**	**110**	**108**	**23**	**73**

Estimation of IF reflections for currently installed ALMA bands (B3-B8) and the corresponding possible calibration channel width.
DSS system with 46MHz calibration channel width will guarantee 30dB IRR level for all the bands.



Degradation of the analogue IRR level vs. offset frequency from the calibration point *df*. Here the period of IF reflections is taken 1000MHz.

SUMMARY

- Digital Sideband Separating can strongly relax requirements for analog components of 2SB SIS receivers, providing at the same time the sideband rejection up to 40dB.
- Callibration stability proved stable on 24 hours and 9 mixer reset cicles (deflux, demagnitisation)
- The channel width of 46 MHz guarantees IRR above 30dB current ALMA receivers.

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