# Digital Front-End Development for ALMA

Baryshev, Andrey

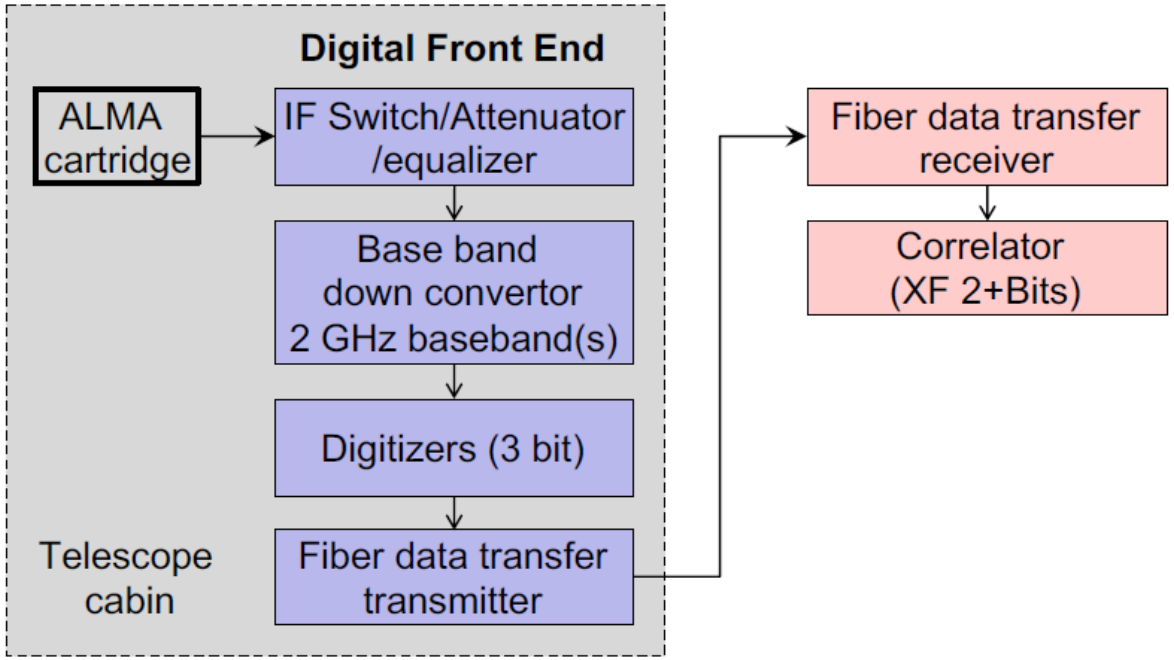
*DOI:*
10.5281/zenodo.3240315

# Digital Front-End Development for ALMA

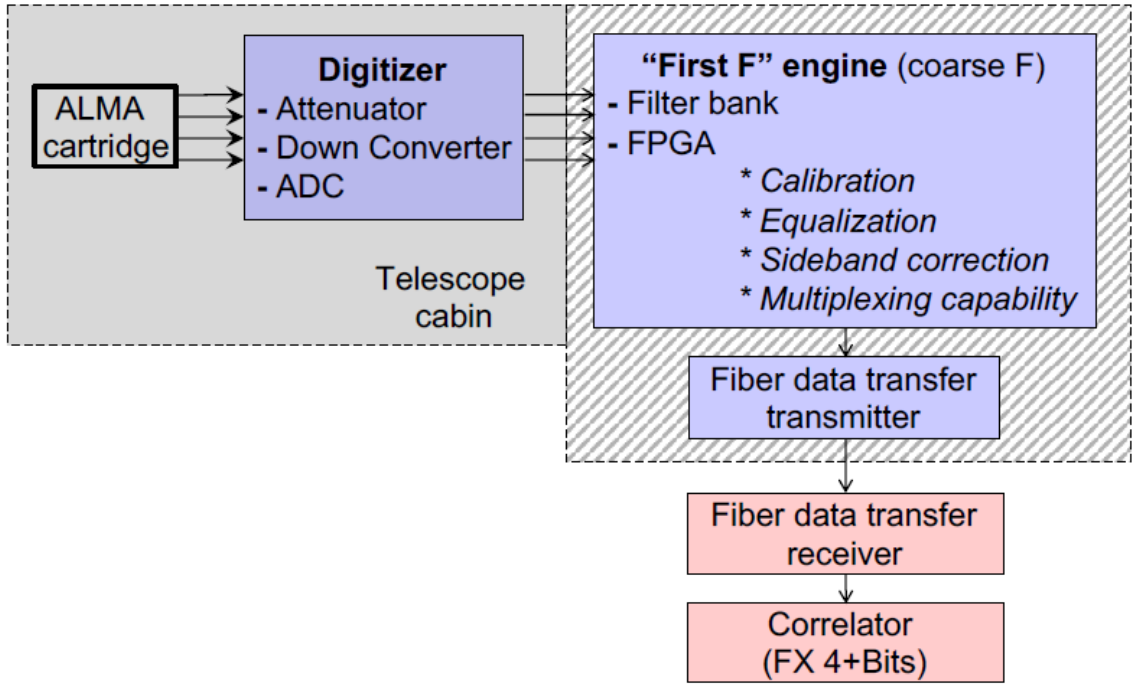
A. M. Baryshev, A. Khudchenko, S. Ashton,
A. Baudry, R. Finger, N. Whyborn, J. Weintroub,
A. Wootten, T.  Mroczkowski, A. Gonzalez,
F. P. Mena, S. Gauffre, B. Klein

# What is digital front end

## Current ALMA




## Digital front end



# Digital front end processing steps

- Analog transport and switching from cartridges
- Analogue levelling amplification
- Baseband split (if needed)
- Digitization (>5 ENOB)
- Coarse complex FFT (1024 spectral channels)
- Baseband equalization and sideband calibration (full speed)
- Trimming lower 4 bits, formatting (inverse FFT if neded), and data transport

# ALMA digital Front end WG

## Activities

- Roadmap document as input
- To study current and discuss realistic future ALMA front-end/backend specifications based on technology now and projection in 10 years
- Propose and study different digital front-end digitization and processing architecture options and make trade-off study with projection in 10 years (including costing)
- Select candidate architecture for detailed study/prototyping

# Specifications

| Parameter | Old requirement | New requirement |
|---|---|---|
| Receiver IF bandwidth (per sideband per po-larization) | 4 GHz (IF 4-8 GHz for 2SB or 4-12 GHz for 1SB and DSB) | At least 8 GHz (IF 4-12 GHz); with a goal of 16 GHz (IF 4-20 GHz) |
| Continuous IF cover-age | Anti-aliasing filters result in the loss of about 125 MHz for each 2 GHz baseband resulting in a total usable instantaneous bandwidth of ~7.5 GHz | The processed IF band-width shall cover at least a 3:1 frequency ratio with no gaps or lost coverage at the IF band edges |
| Front-end Sideband Rejection Ratio | >10 dB for 90% of the IF range (SSB and 2SB)<br>>7 dB over 100% of the IF range (SSB and 2SB) | >20 dB with a goal of<br>>30 dB under all conditions |
| Digital Base band calibration | Analogue equalization only, limited to 2 GHz sub-bands | True digital base band correction with 10 MHz channel spacing * |
| Correlator bit depth and transport | 2 and 3 | full 4 bits for all frequency resolution modes/ full IF band |

# Specification continued

| Parameter | Old requirement | New requirement |
|---|---|---|
| Analogue inputs | 2 polarizations, 2 side-bands, 10 frequency bands | 2 x 2 x 10 with the possibility to extend |
| Digital processing channels | 2-pols x 4 basebands | 2-pols basebands |
| Compatibility | | DFE concept should be able to support operations with current/upgraded ALMA XF correlator, ALMA compact array FX correlator, possible future FFX correlator upgrade by adapting FPGa software only. |
| Flexibility | | Where practical the de-sign shall support up-grades to increase the number of IF channels and/or increased IF band-width and/or multiplexing. |

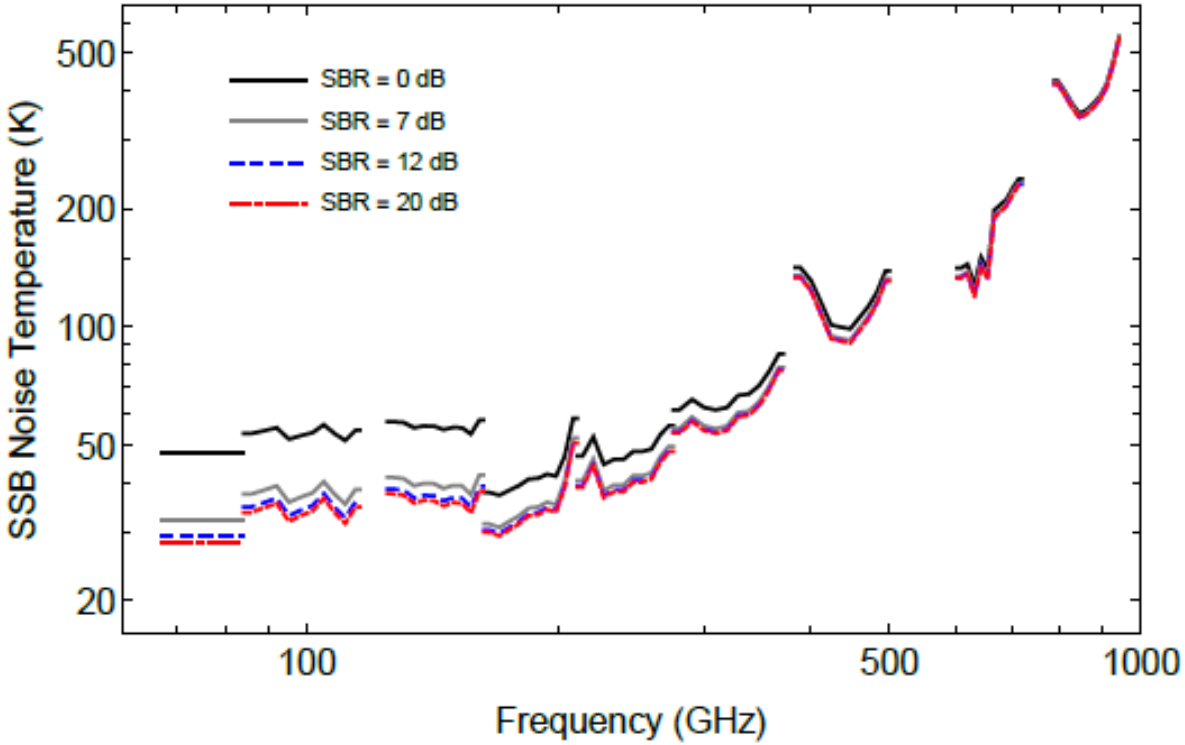
**2% efficiency increase is equivalent of 1 additional antenna**

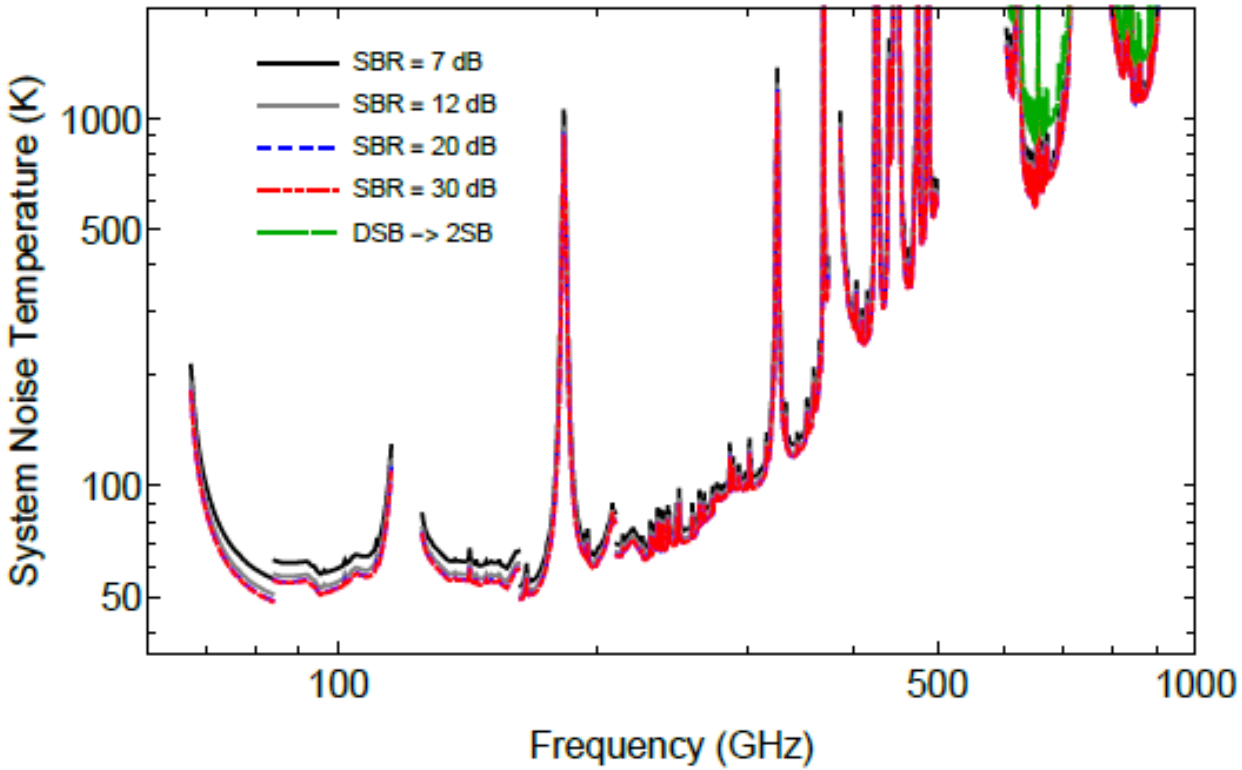
# Dynamic range

| Source | Dynamic range | Required quantization efficiency | Notes |
|---|---|---|---|
| Sky brightness changes | 3 dB | 96% | Neil Phillips (private communication). |
| IF level setting error | 1 dB | 96% | Combination of IF attenuator resolution and setting error. |
| Sub-total: science targets | 4 dB | 96% | System Requirements #227.1 & #521 |
| AtmCal calibration sequence | 12 dB | 75% | Hot load versus cold sky (see Table 7 for the band dependent values). |
| IF level setting error | 1 dB | 75% | Combination of IF attenuator resolution and setting error. |
| Sub-total: flux calibration | 13 dB | 75% | System Requirement #227.2 |
| Solar observations | 12 dB | 90% | TBC Receiver detuning or optical attenuator. |
| IF level setting error | 1 dB | 90% | Combination of IF attenuator resolution and setting error. |
| Sub-total: solar observing | 11 dB | 75% | Provisional value, TBC. |

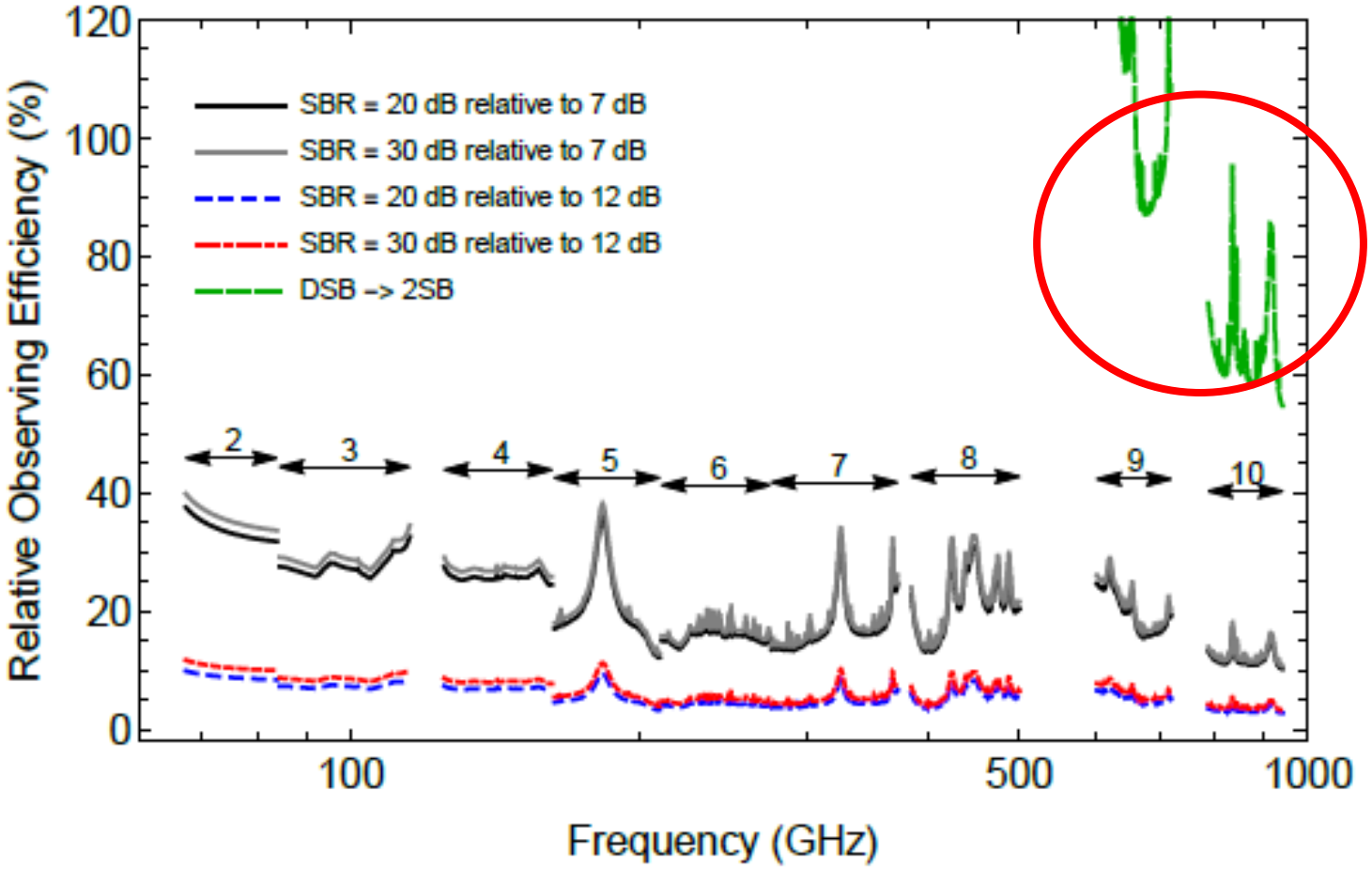
**At least 5 ENOB are needed**
**Goal: NO analogue attenuation**
**Change when calibration loads or sun observing**

# Effect of sideband ratio

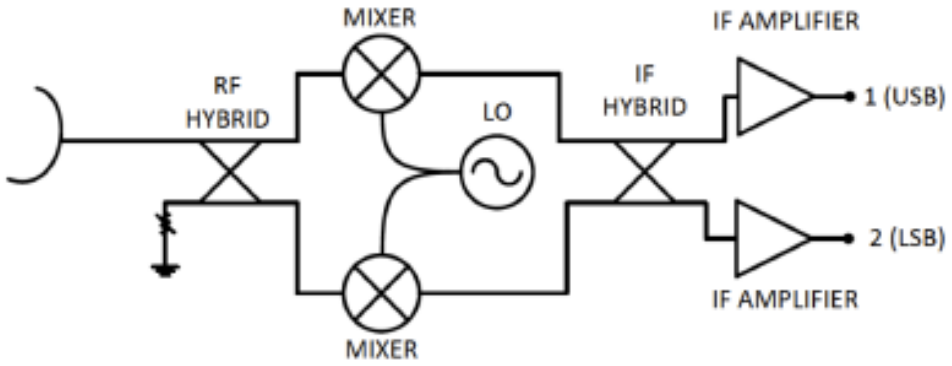


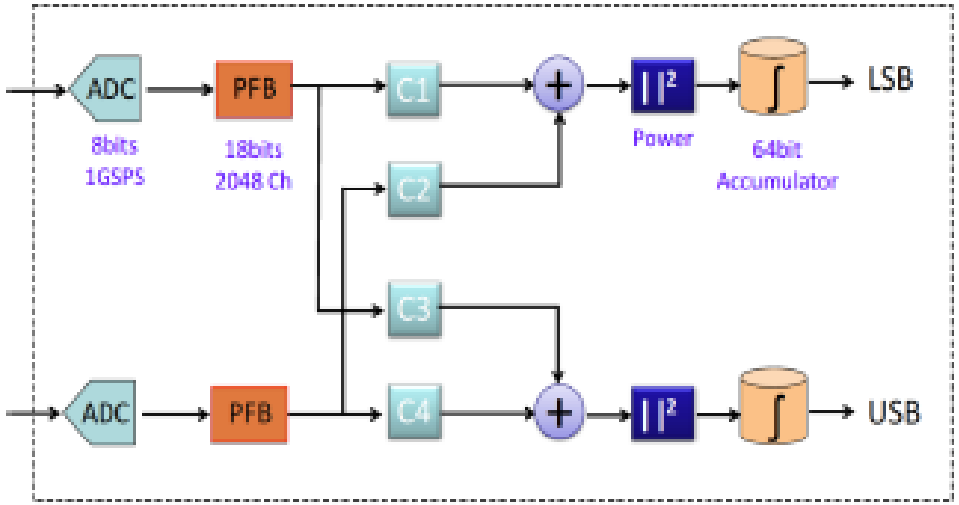



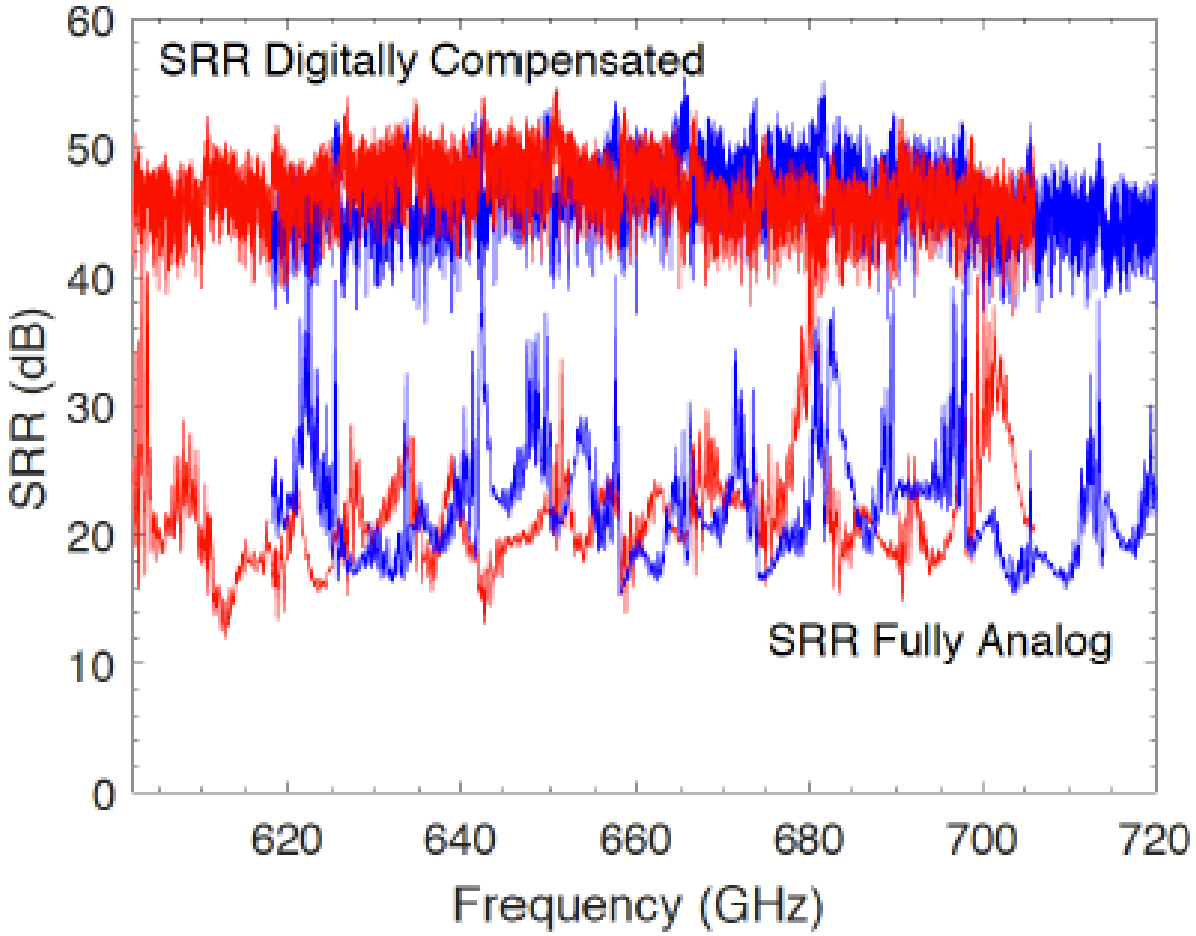
# Observing efficiency vs SBR



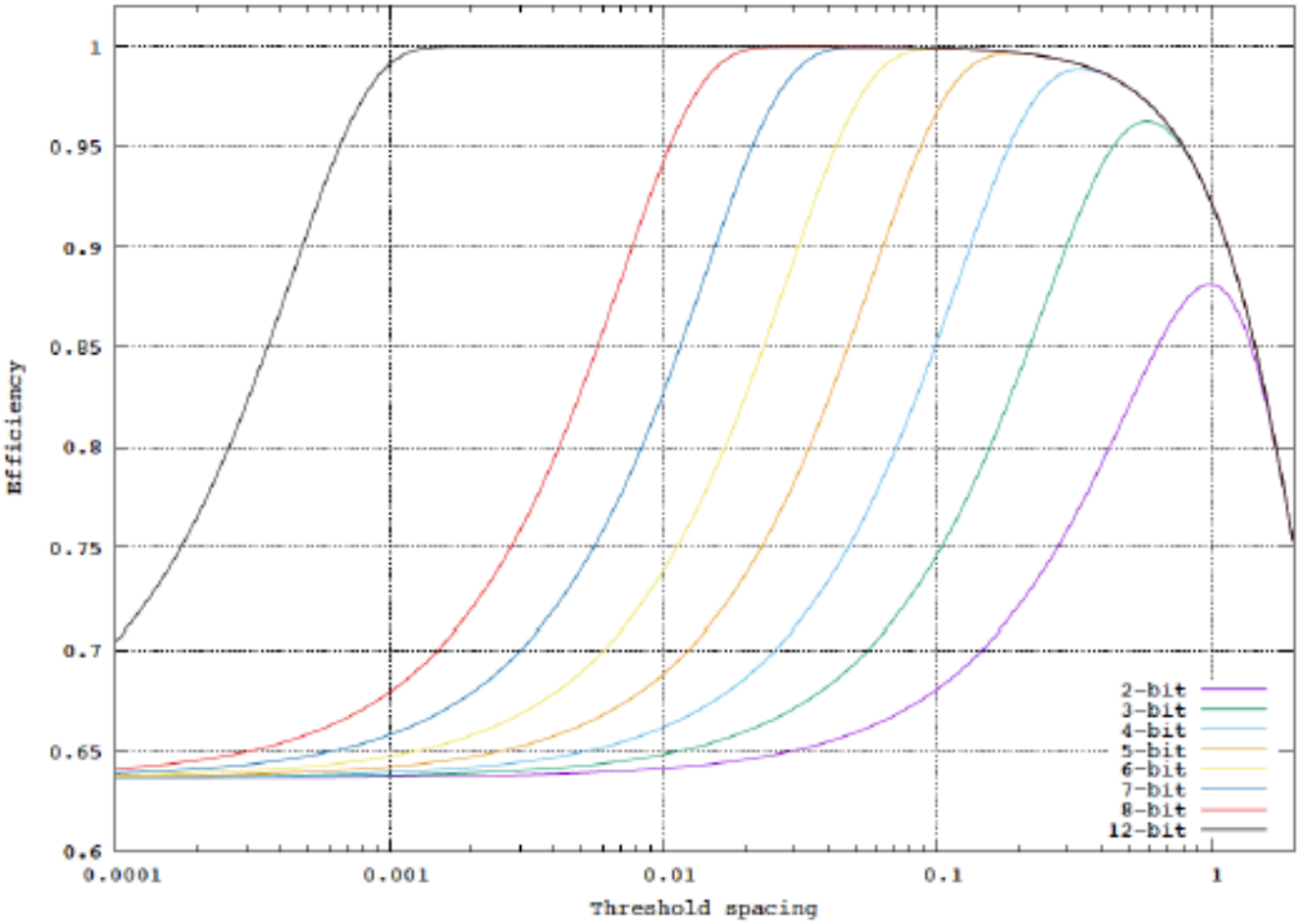
# Sideband correction



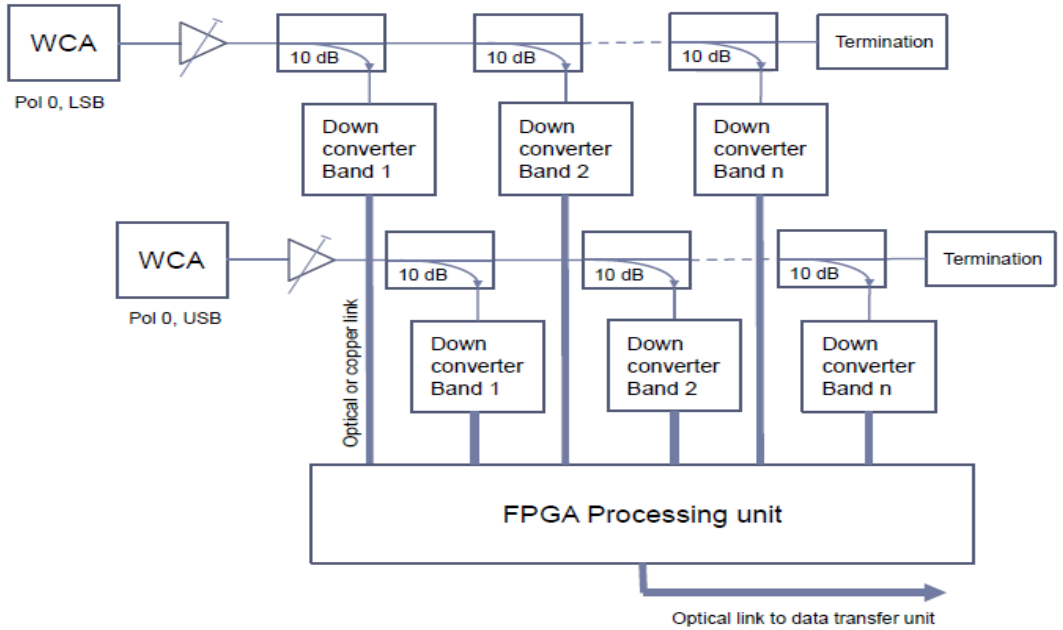
# Quantization efficiency

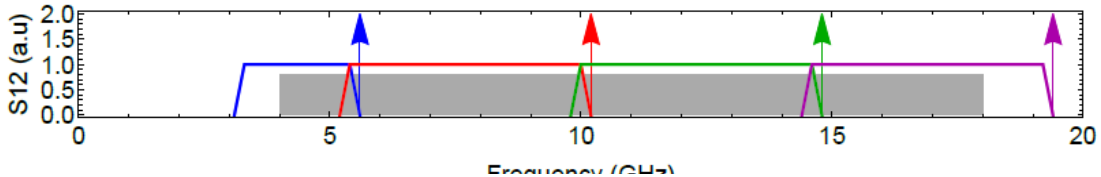



**>10% improvement 2bit -> 4bit**

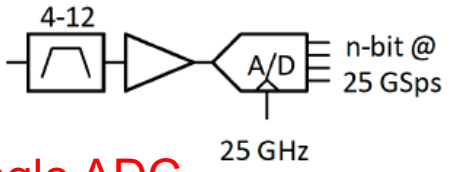
# Digitizing options

## Down converter to baseband

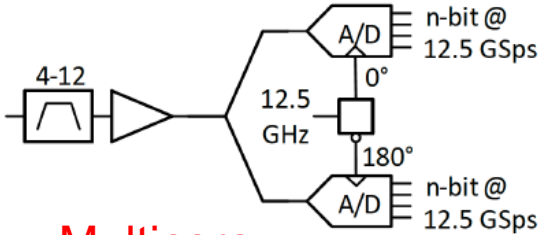


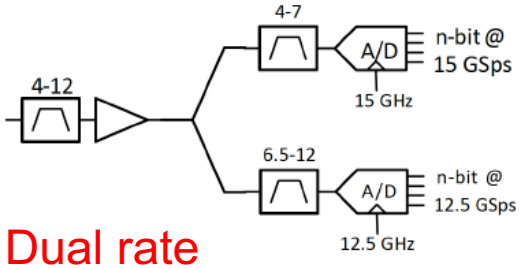

## Full band at once




Single ADC

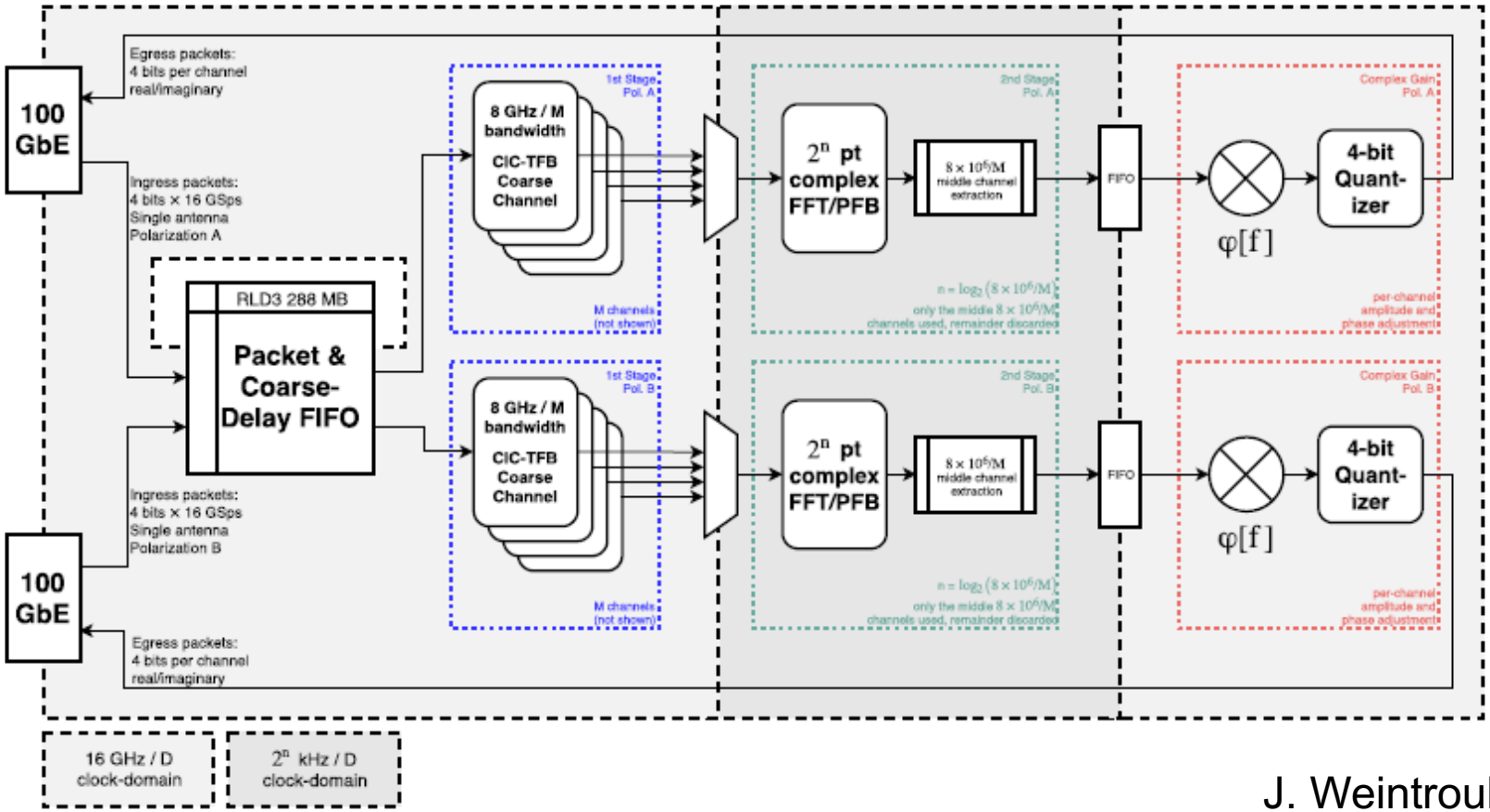



Multicore




Dual rate

# Correlator!!!!!!!




**FX, of course**

J. Weintroub

# Data transport and FPGA digital power

- Data transport: enough optical fibber available, switch to standard TCP (UDP) protocol and standardized telecom equipment
- Even todays FPGAs can process 4 inputs 1 band, power dissipation is not a problem

# Conclusion

- We have finalized coherent set of specifications
- We have done initial impact analysis
- We will do trade-off and final review this summer/September

**Preliminary: It is very cost efficient upgrade option to gain performance equivalent  in many antennas**