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Digital Front-End Development for ALMA

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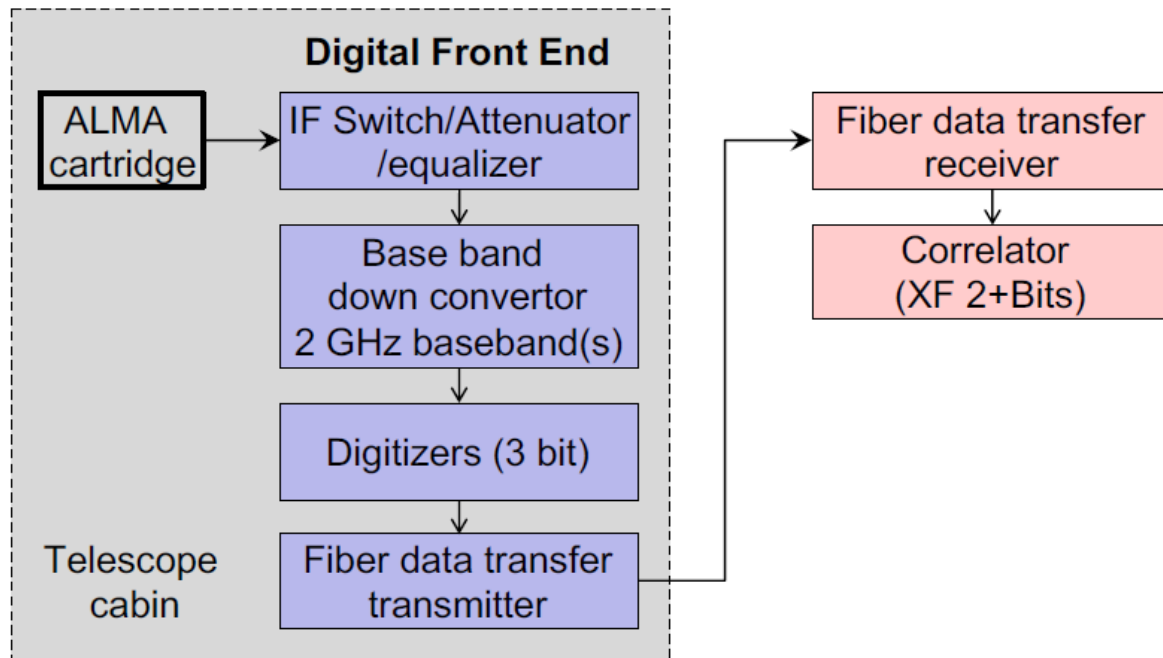


Digital Front-End Development for ALMA

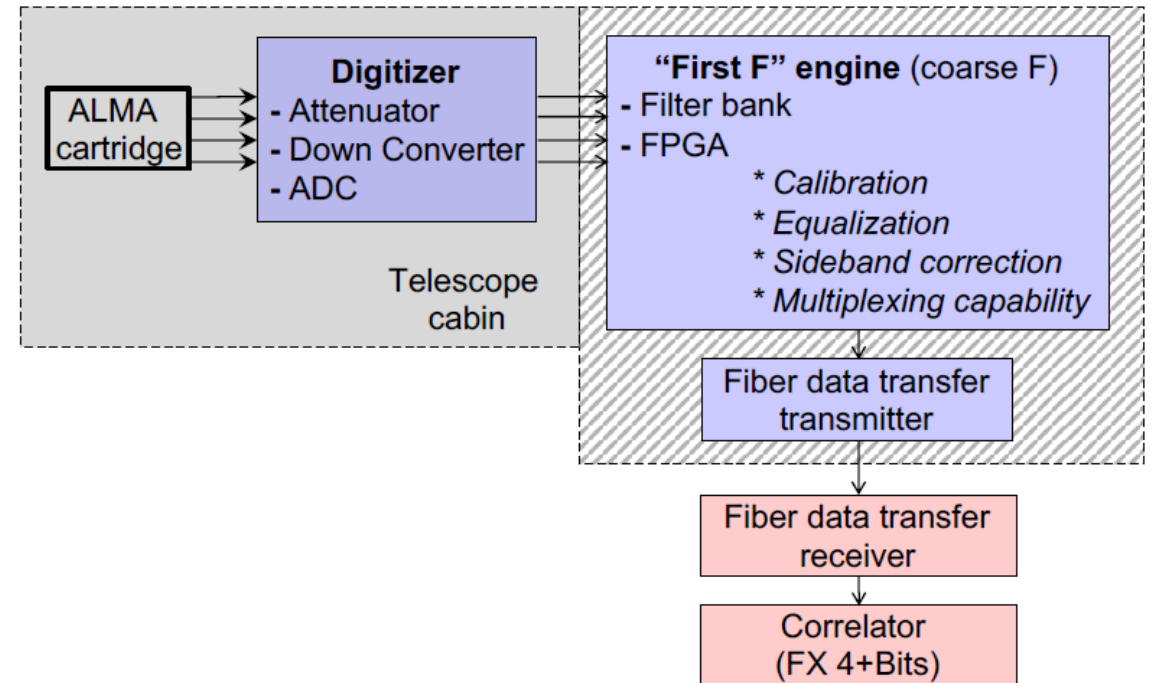
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What is digital front end

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 needed), 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 polarization)	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 coverage	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 bandwidth 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) >7 dB over 100% of the IF range (SSB and 2SB)	>20 dB with a goal of >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 upgrades 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



ALMA development workshop

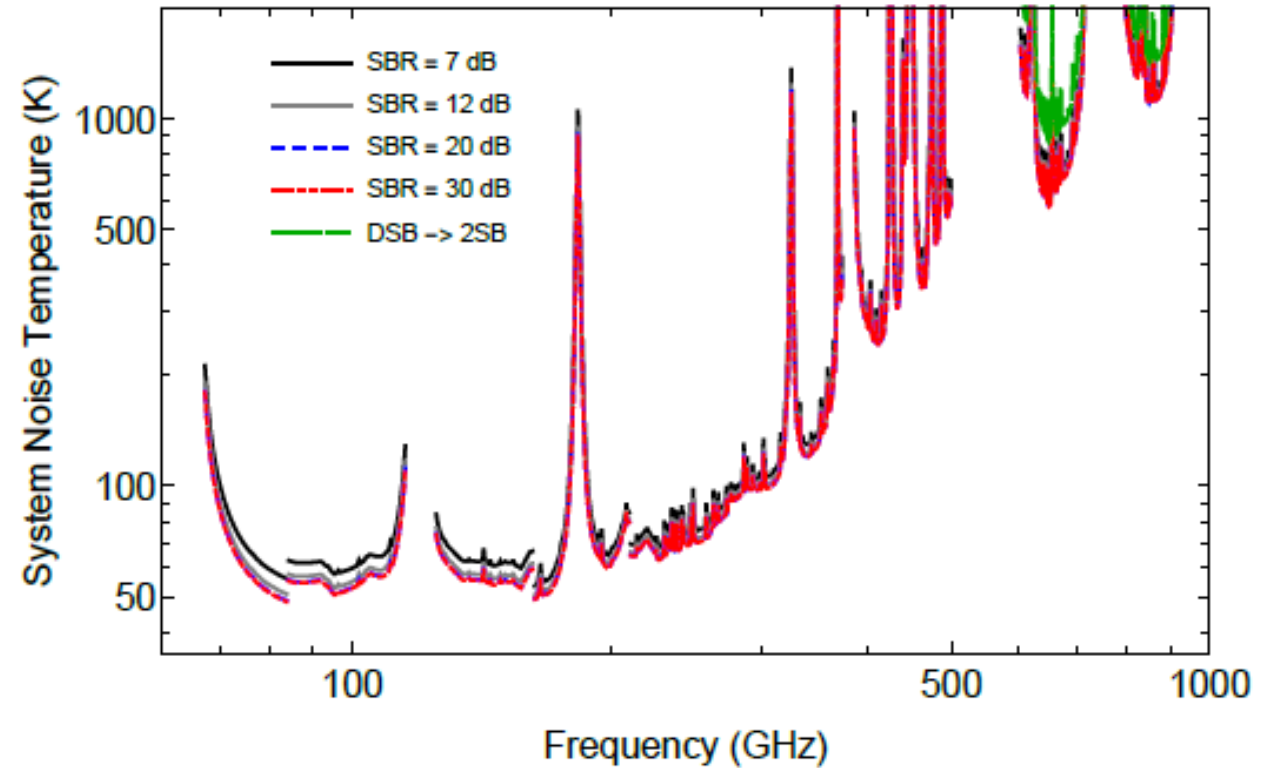
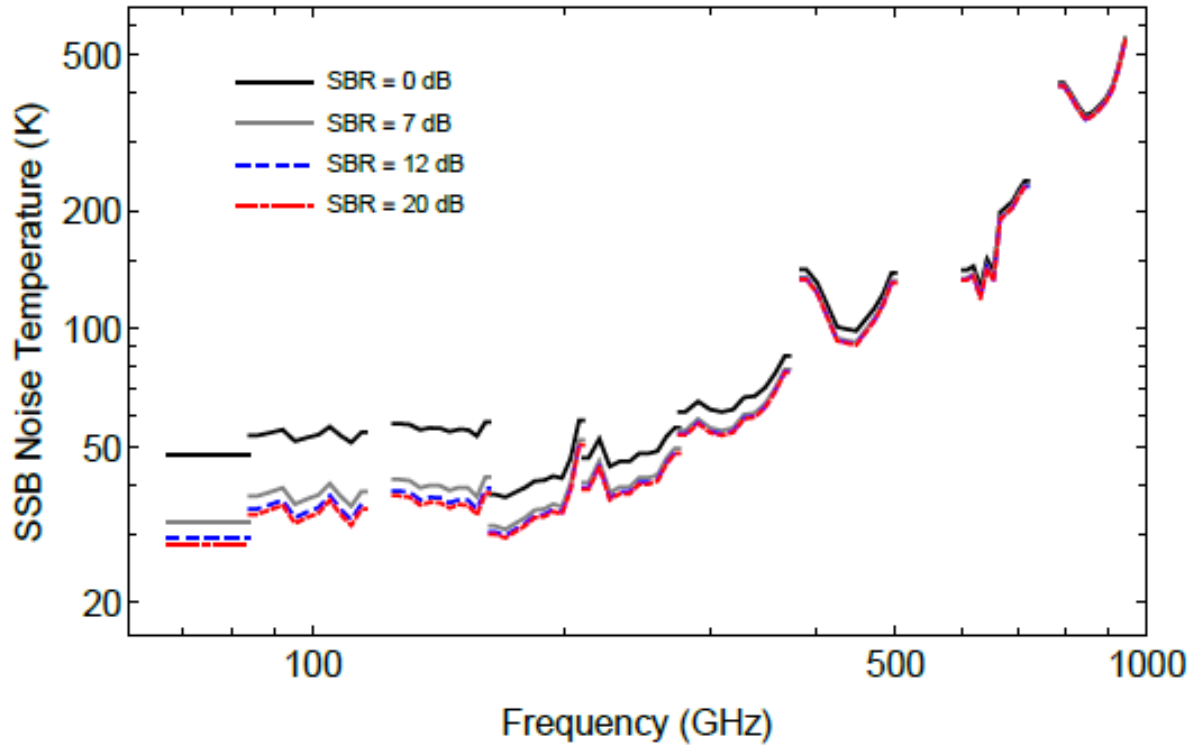
Dynamic range

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

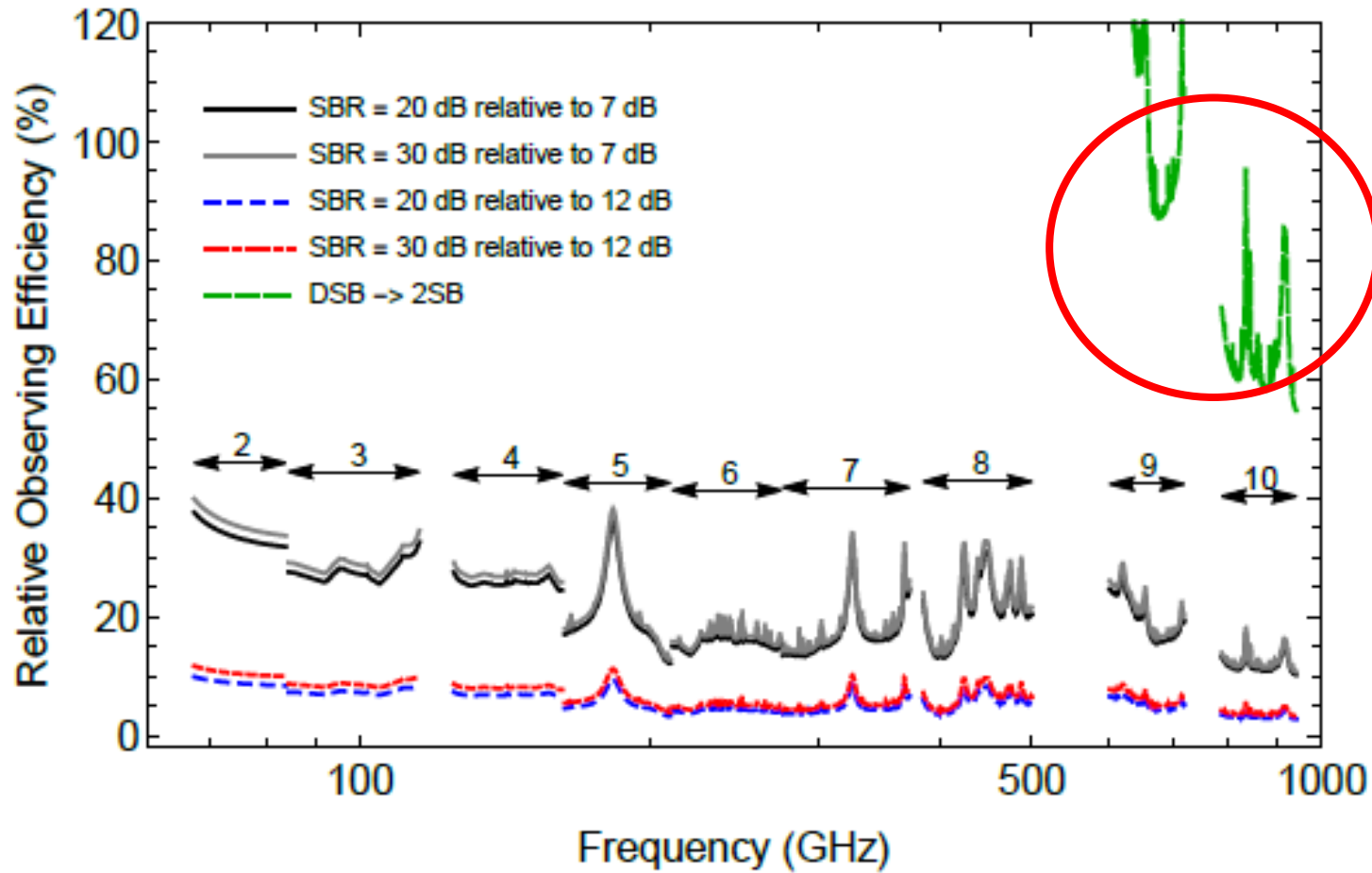
At least 5 ENOB are needed
Goal: NO analogue attenuation
Change when calibration loads or sun observing



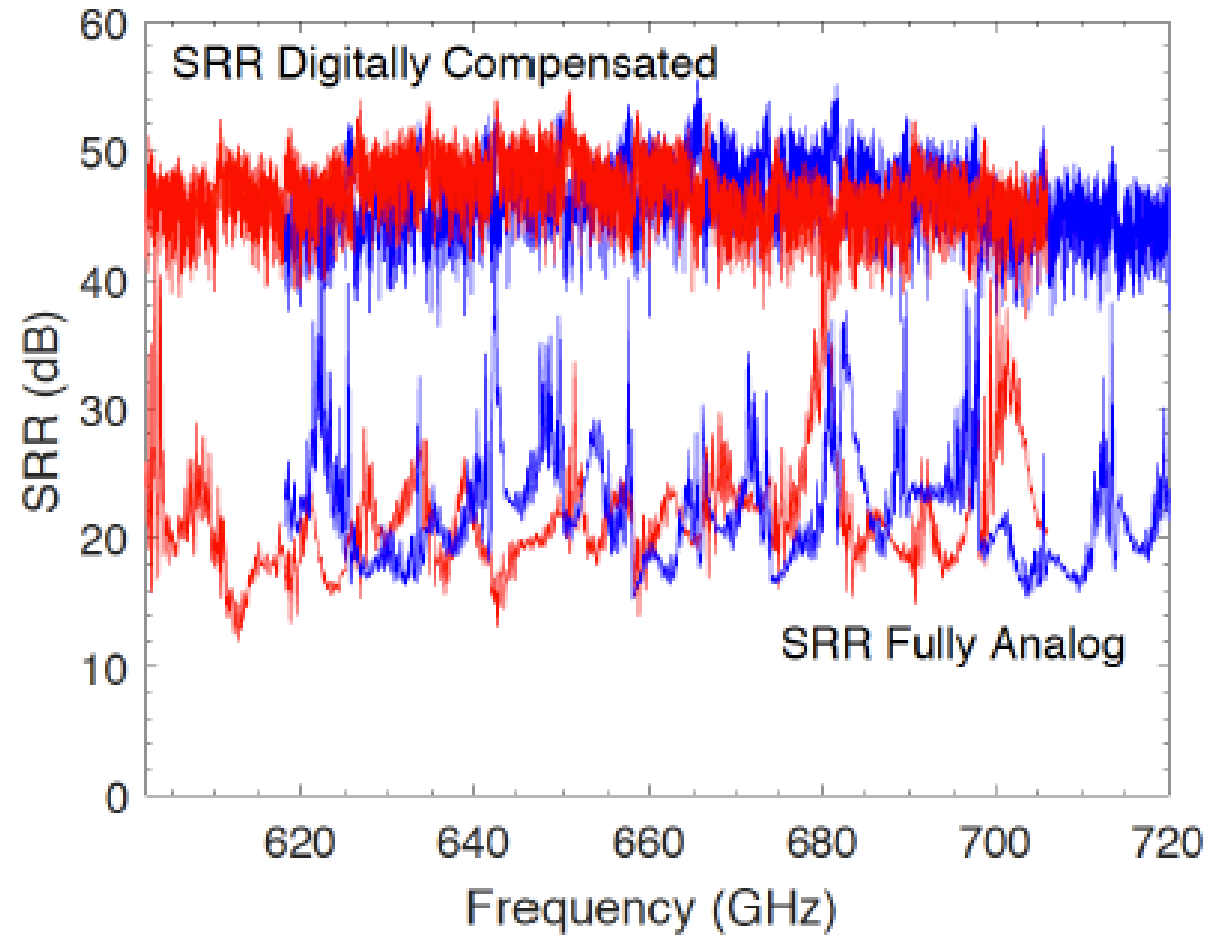
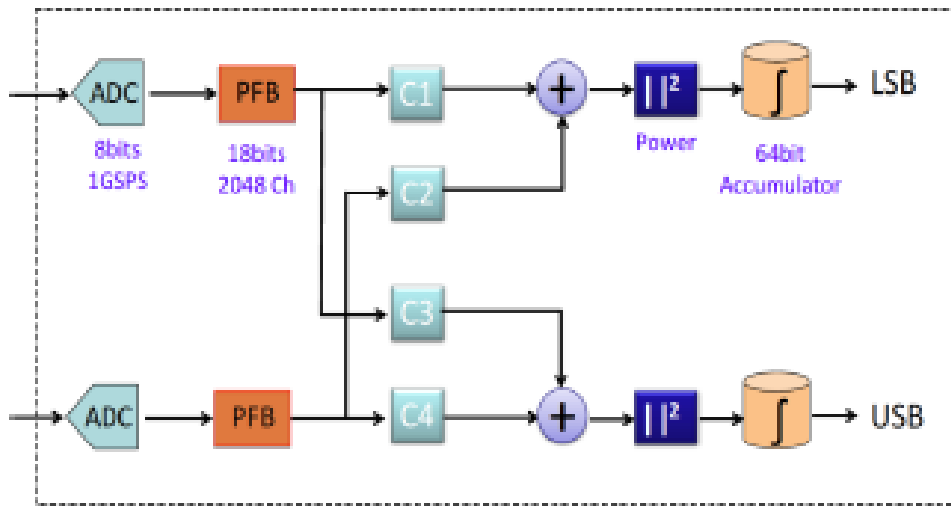
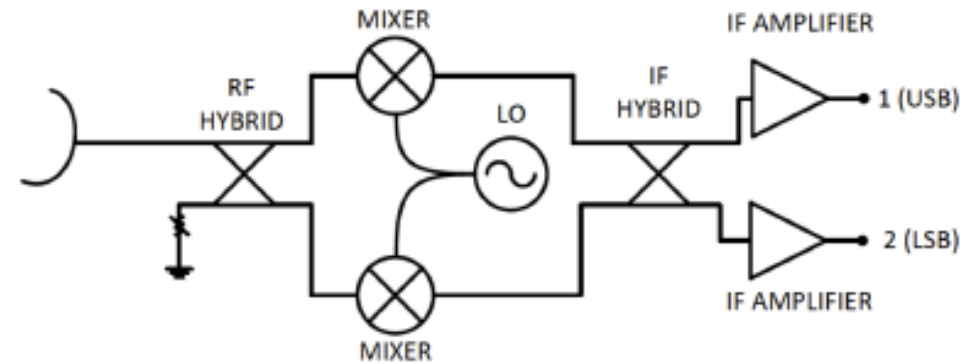
Effect of sideband ratio



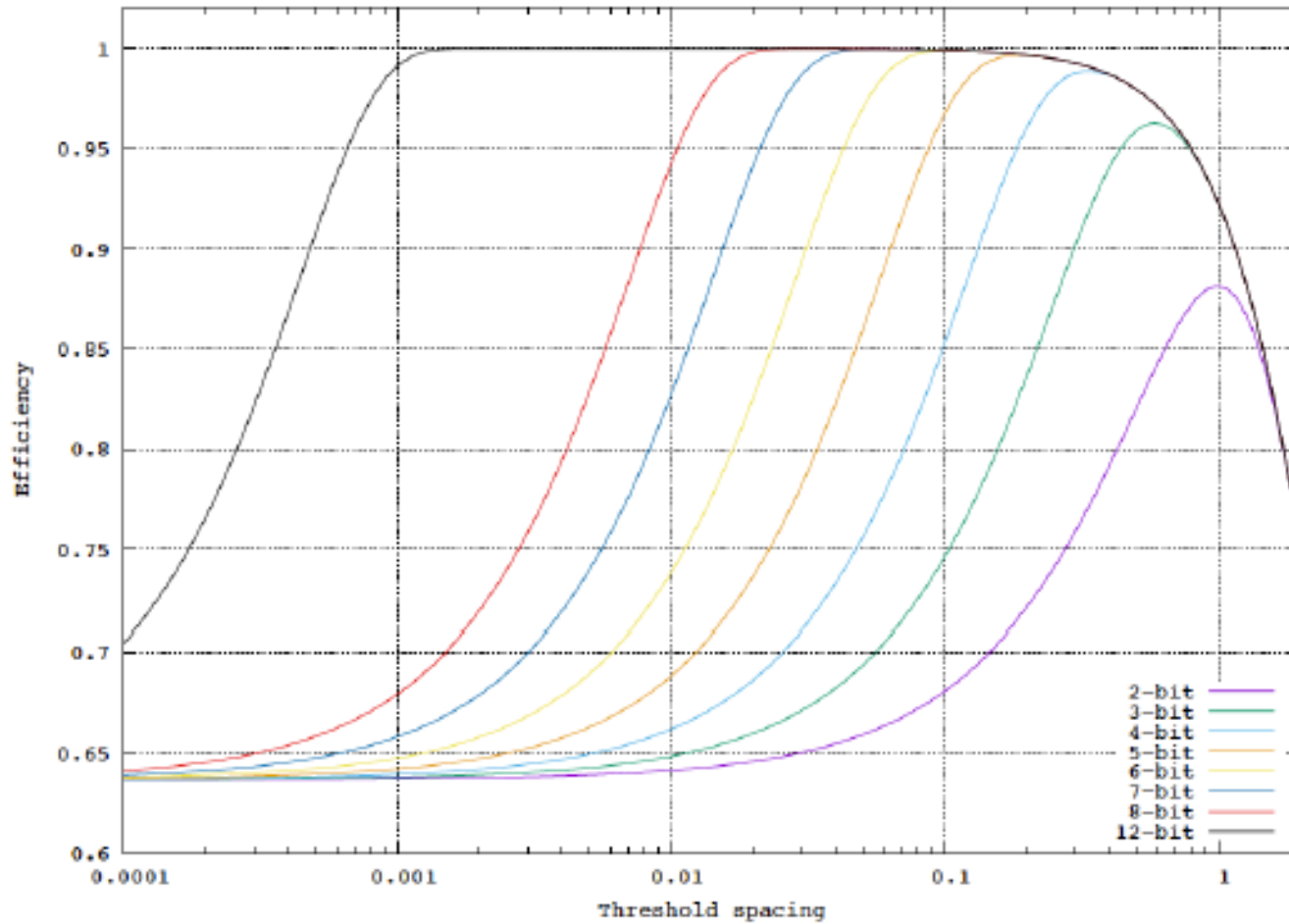
Observing efficiency vs SBR



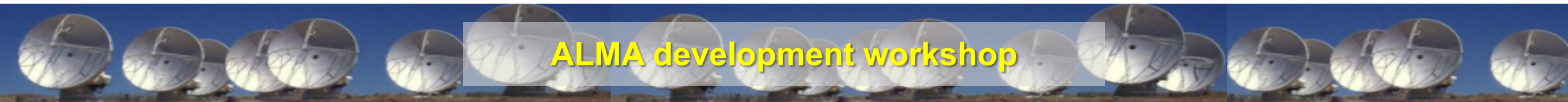
Sideband correction



Quantization efficiency

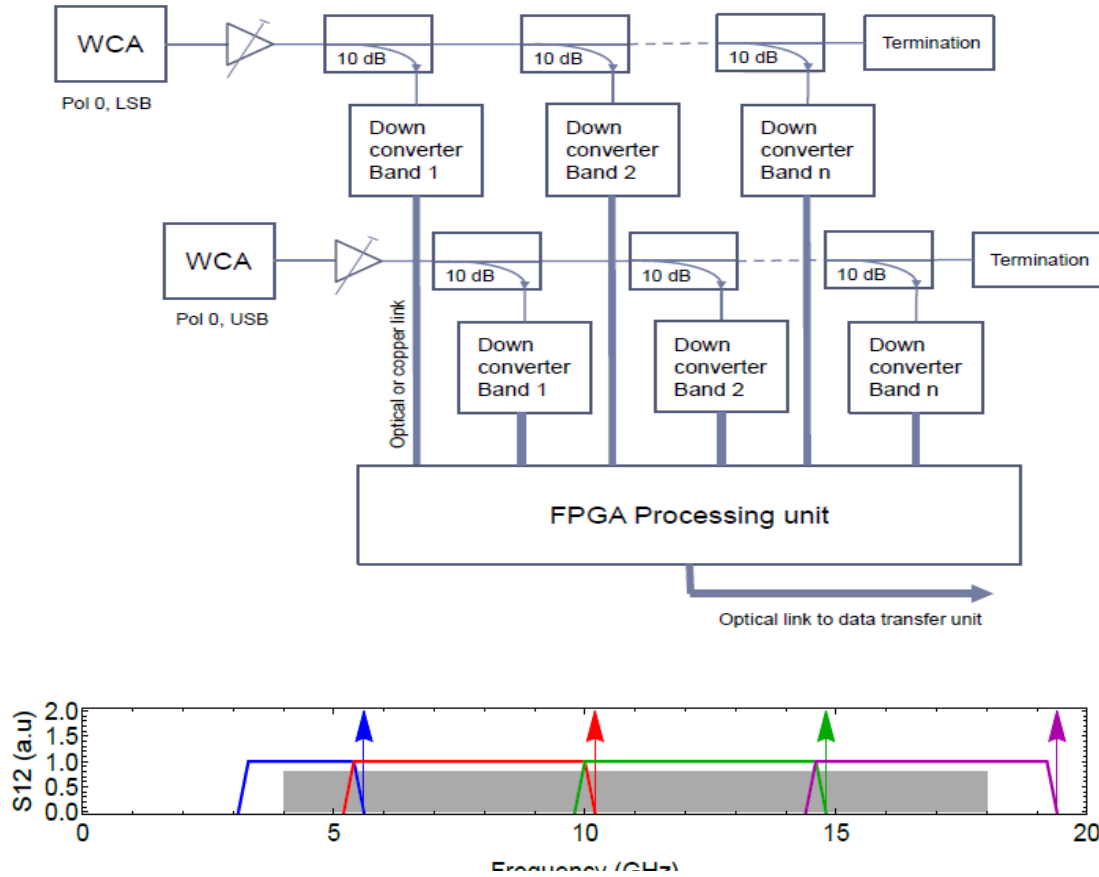


>10% improvement 2bit -> 4bit

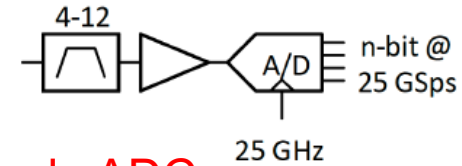


Digitizing options

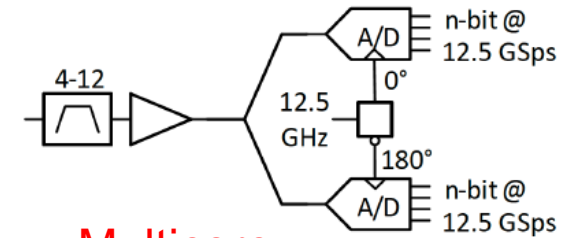
Down converter to baseband



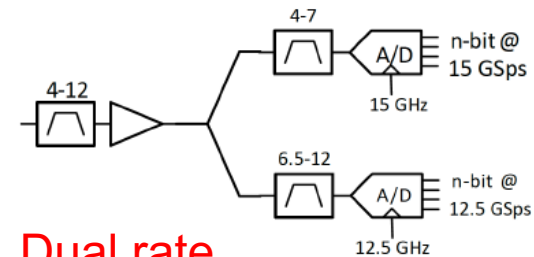
Full band at once



Single ADC

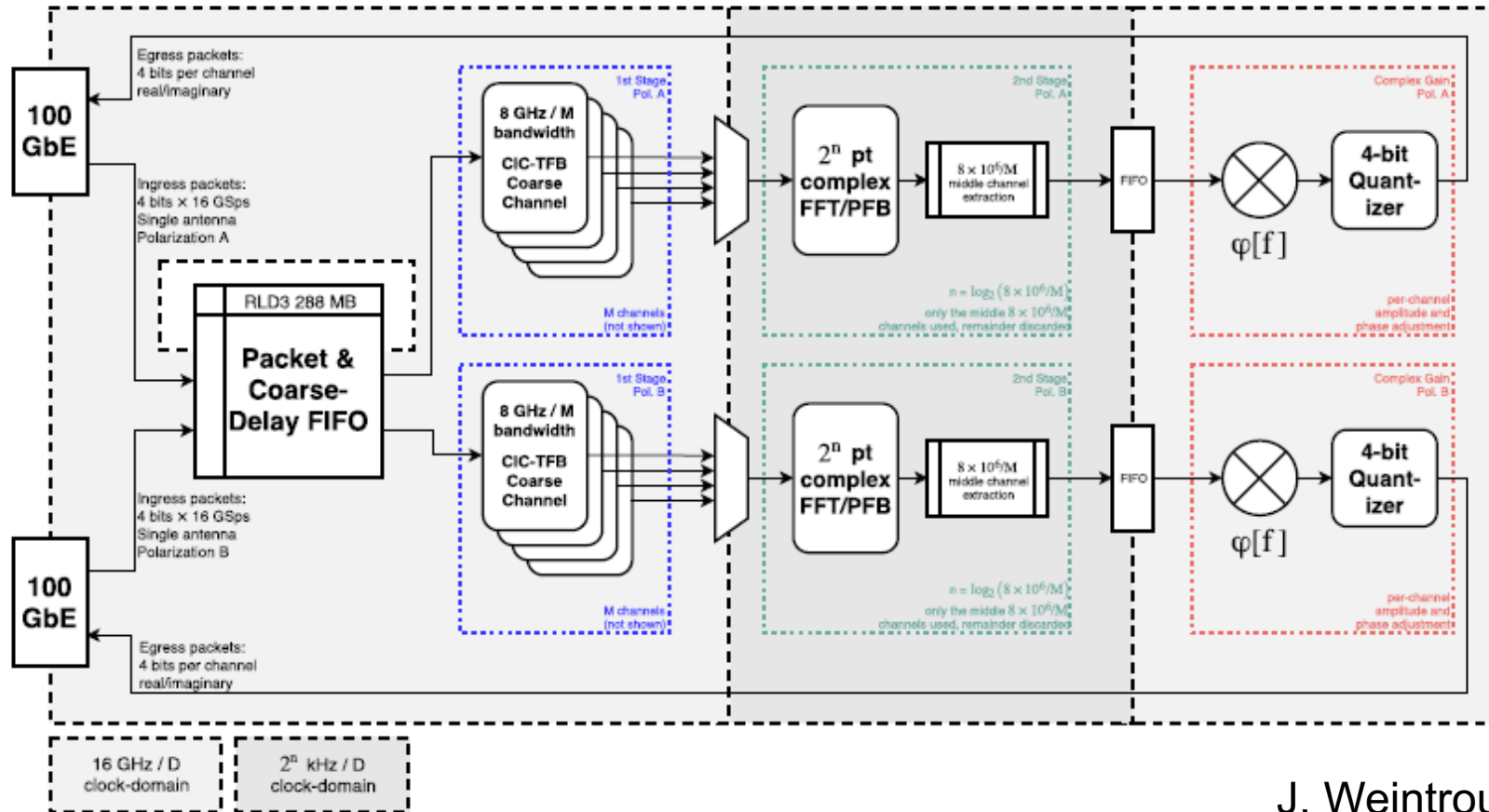


Multicore



Dual rate

Correlator!!!!!!!



FX, of course

J. Weintraub

Data transport and FPGA digital power

- Data transport: enough optical fiber available, switch to standard TCP (UDP) protocol and standardized telecom equipment
- Even today's 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