8th MicroTCA Workshop for Industry & Research

Electromagnetic Compatibility (EMC) in Modern Electronic Standards e.g. MicroTCA.4

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for the LLRF team at DESY
Hamburg, 04.12.2019

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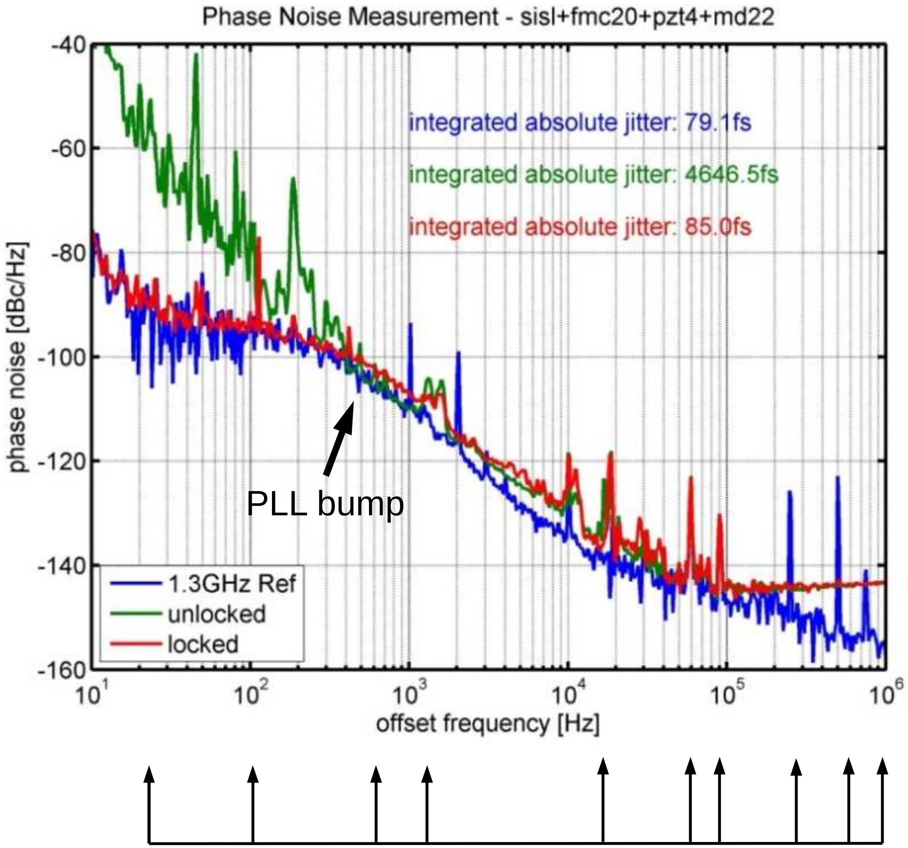
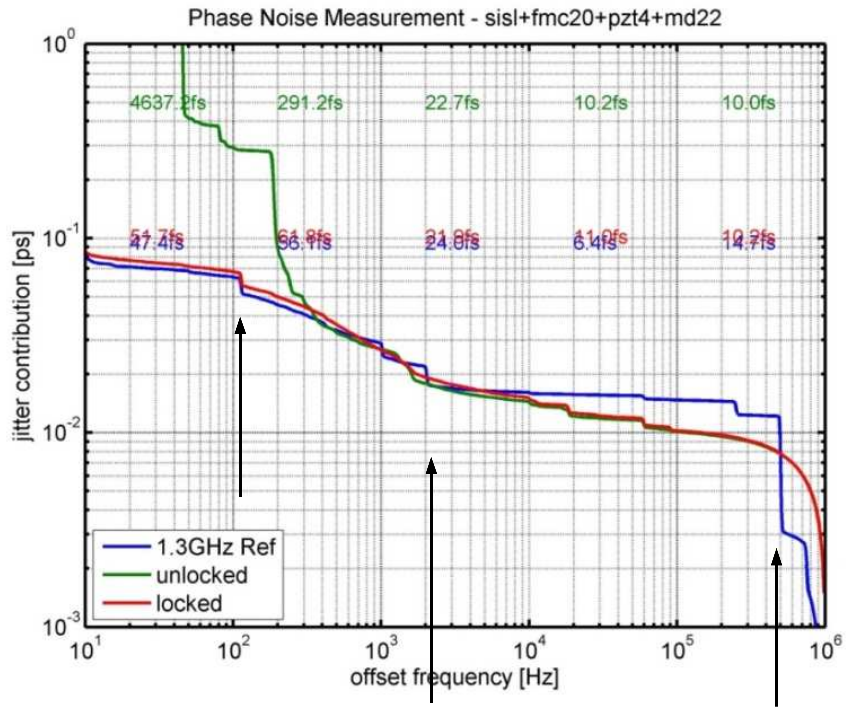
1 Why is EMC important for us ?

FIL

- Example: Laser-RF-Locking, not optimized phase noise spectrum





Do these distortion lines degrade the time resolution ?

$$\overline{\Delta t^2_{f_1,f_2}} = \frac{1}{(2\pi f_0)^2} \int_{f_1}^{f_2} S_\varphi(f)df$$

A distortion free spectrum is a condition to achieve good time resolutions.
Most of the distortions are self-made and can be fixed but some are related to EMC.

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1 Analog meets Digital in Modular Systems

- Commercial ADCs :

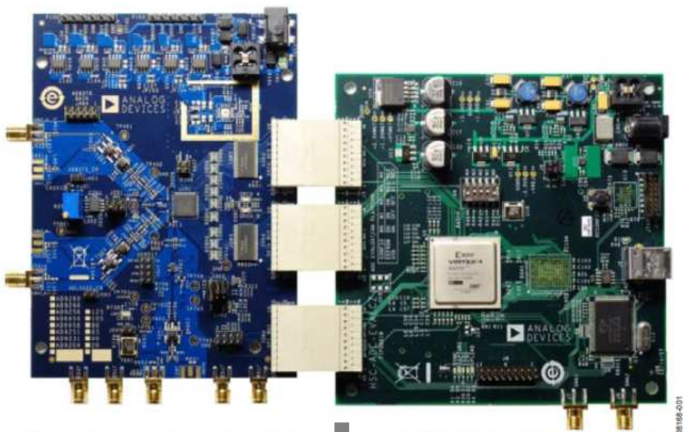
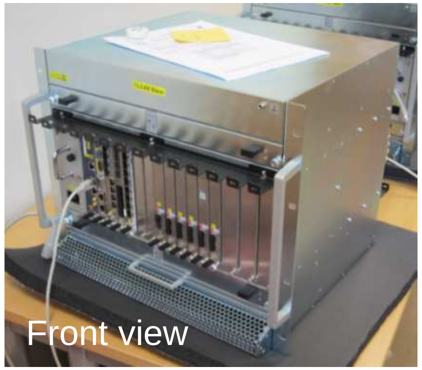
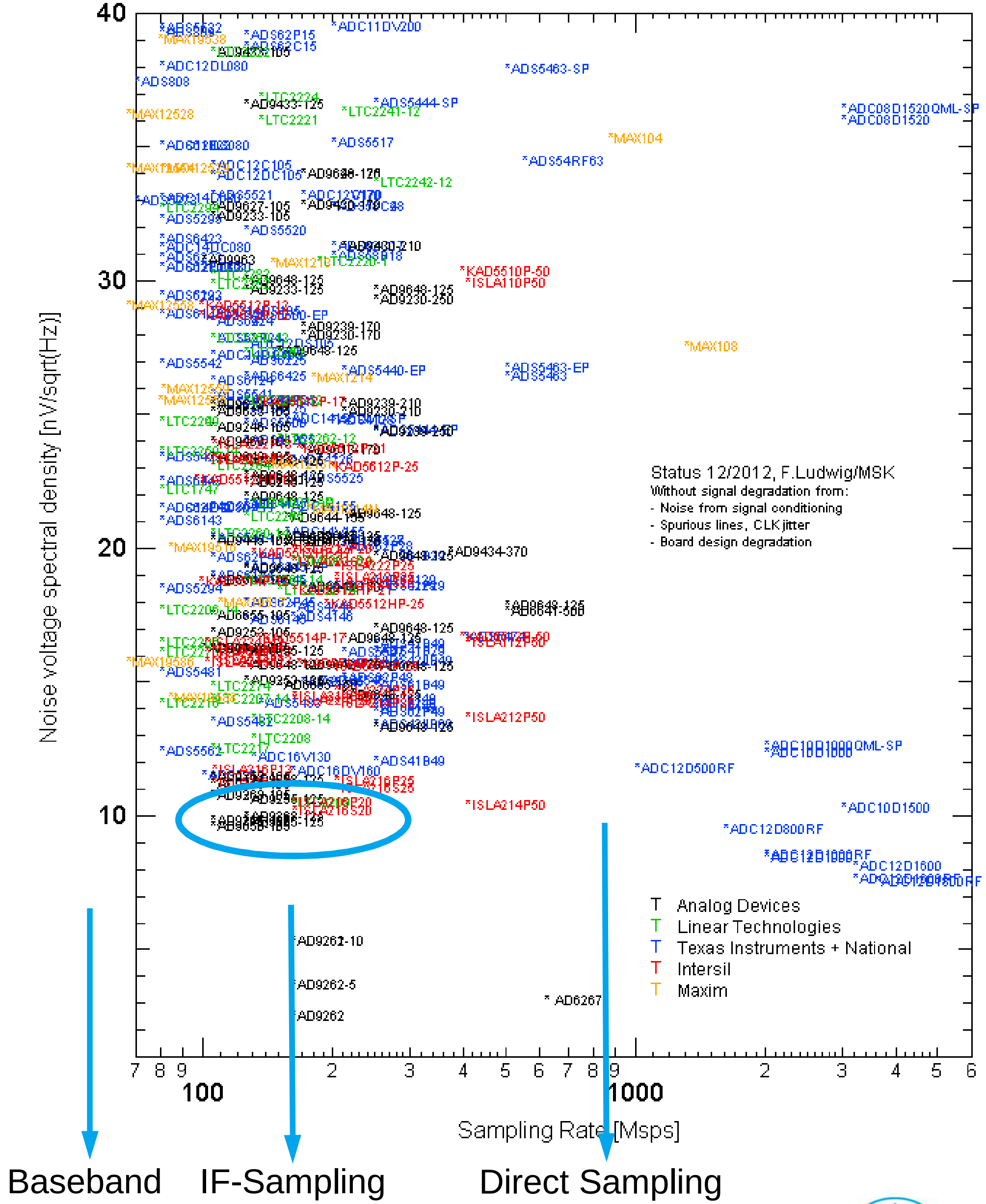


Figure 1. AD9268 and AD9269 Family Evaluatior oard and HSC-ADC-EVALCZ Data Capture Board



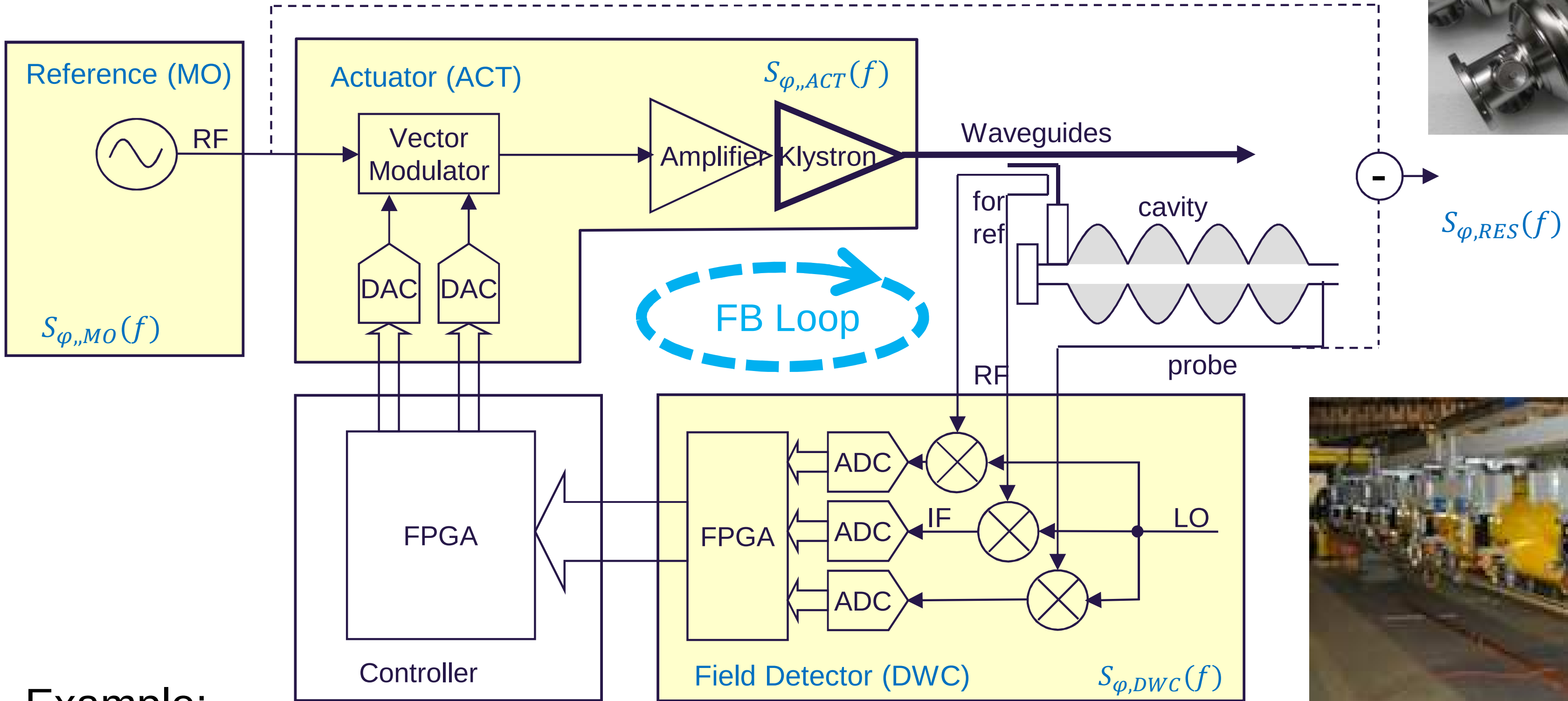
Performance maintained ?

↷ Spurfree spectral ADC data !



1 Low-Level-Radio-Frequency (LLRF) Control

- High-frequency regulation – main noise sources:



<u>Example:</u>

- fs Cavity field stability requirements:

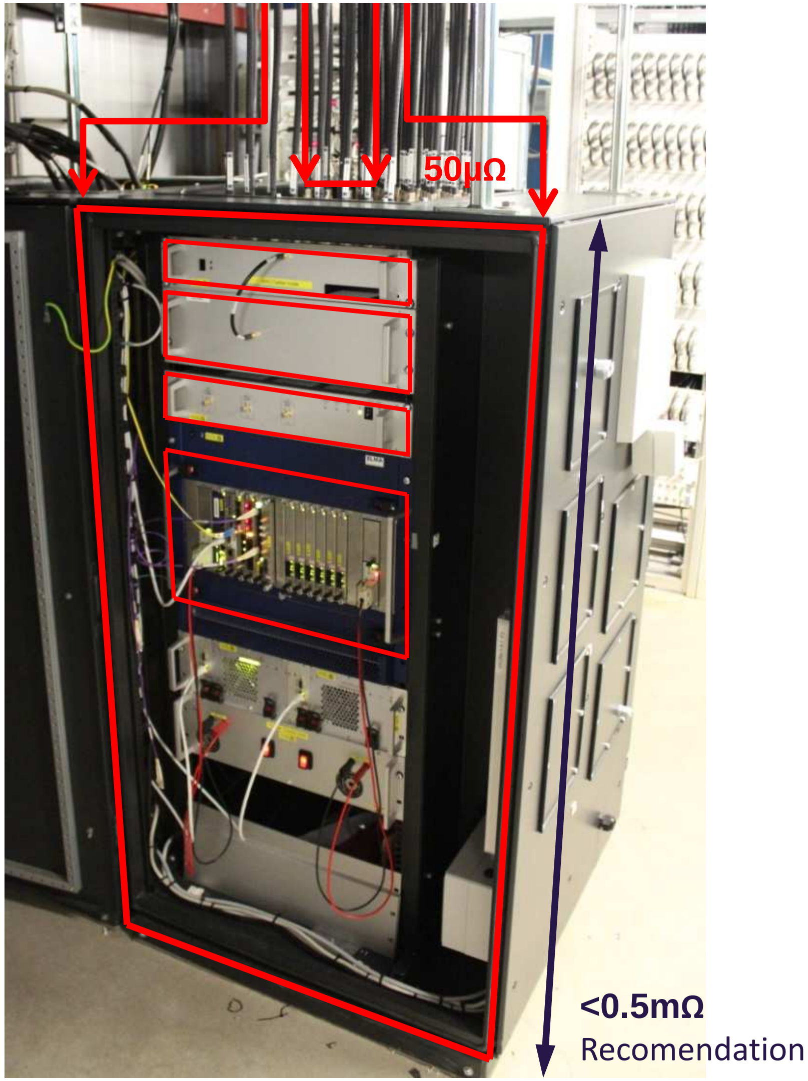
Amplitude stability : <0.005% = 5E-5
Phase stability : <0.005 deg, <10fs @1.3GHz
Typical signal levels in receivers are about 1V:
-> Measurement resolution must be <1V*1E-5=10uV
-> All voltages caused by EMC must be smaller than 10uV!

Typical PCB ground resistances are about 1mOhm:
-> Maximum return ripple current 10uV/1mOhm=10mA

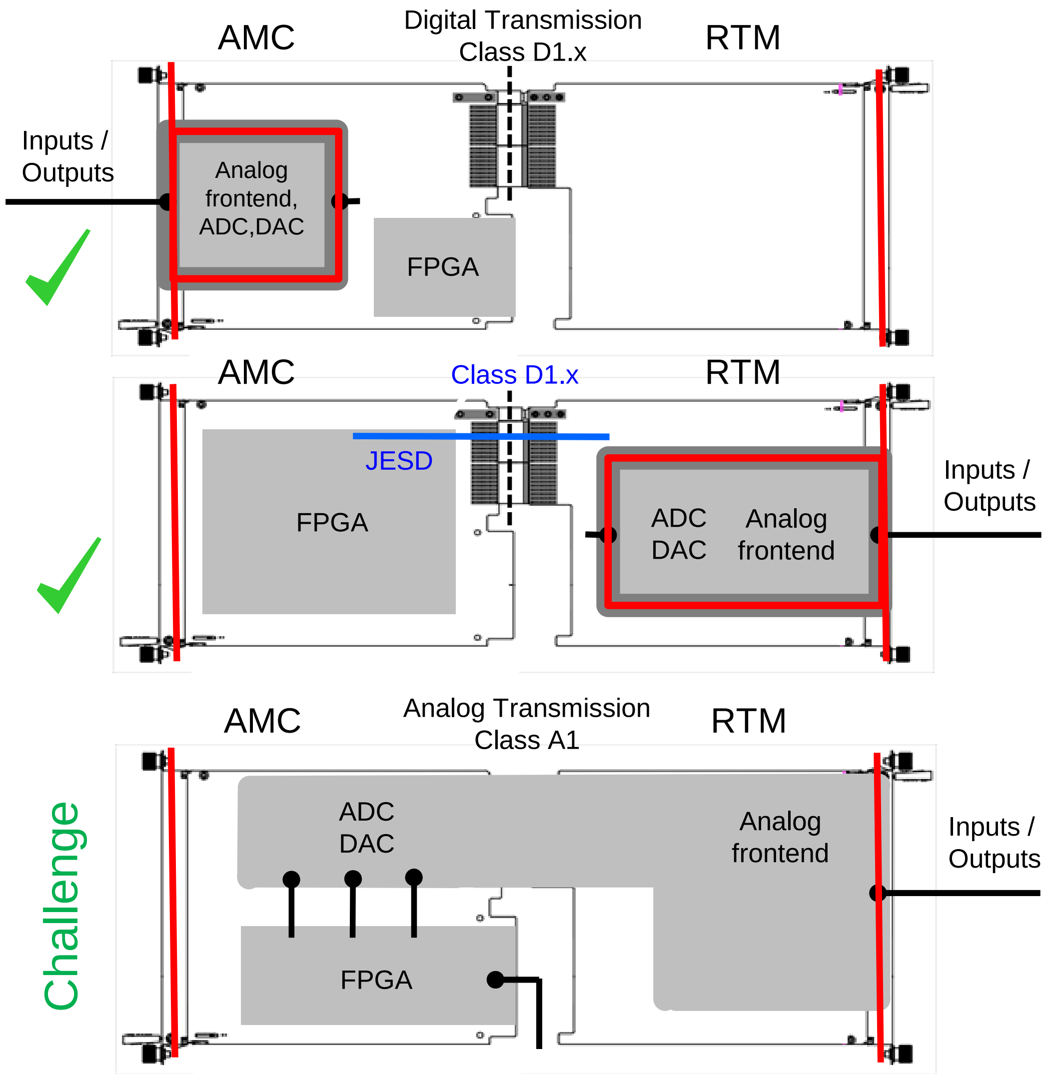
- EMC system planning
- EMC system packaging

1 EMC Zones – System Robustness to External Distortion

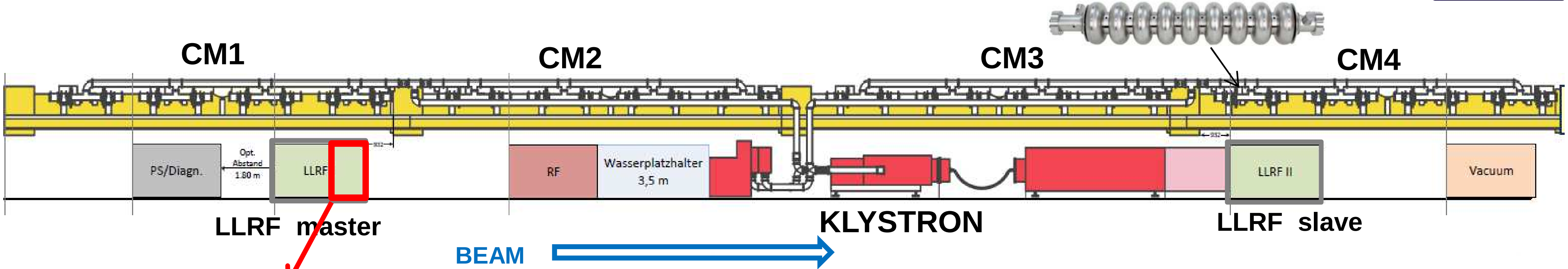
Rack-Level



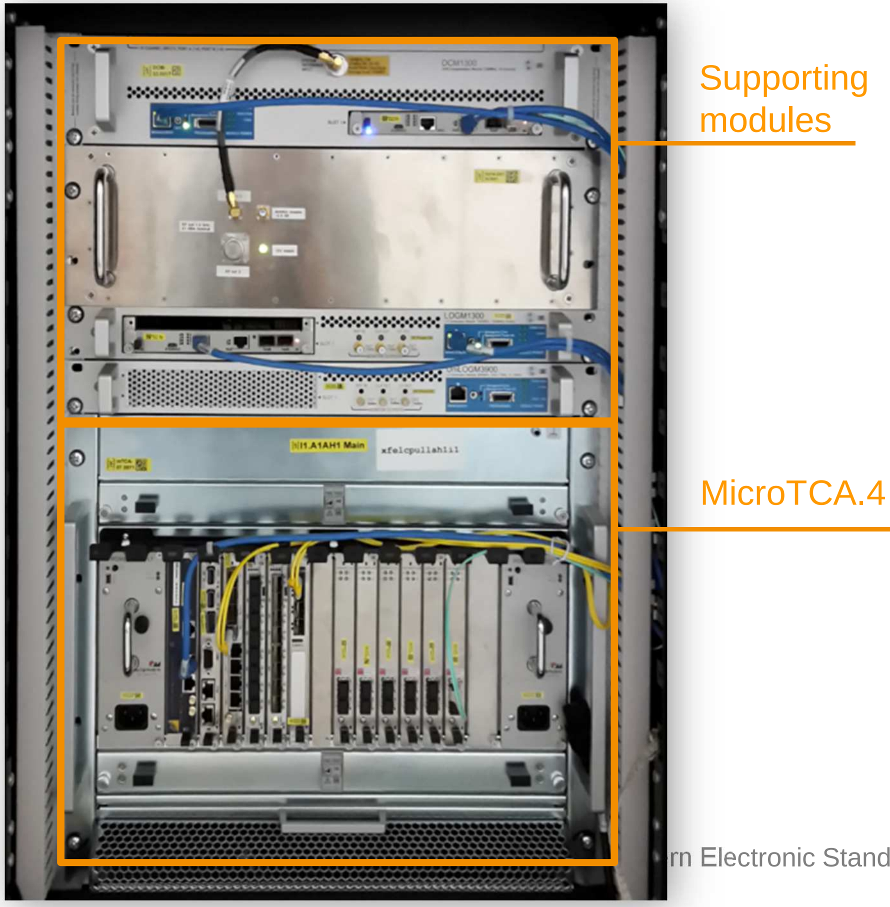
Crate-Level (Modular systems e.g. MicroTCA.4)

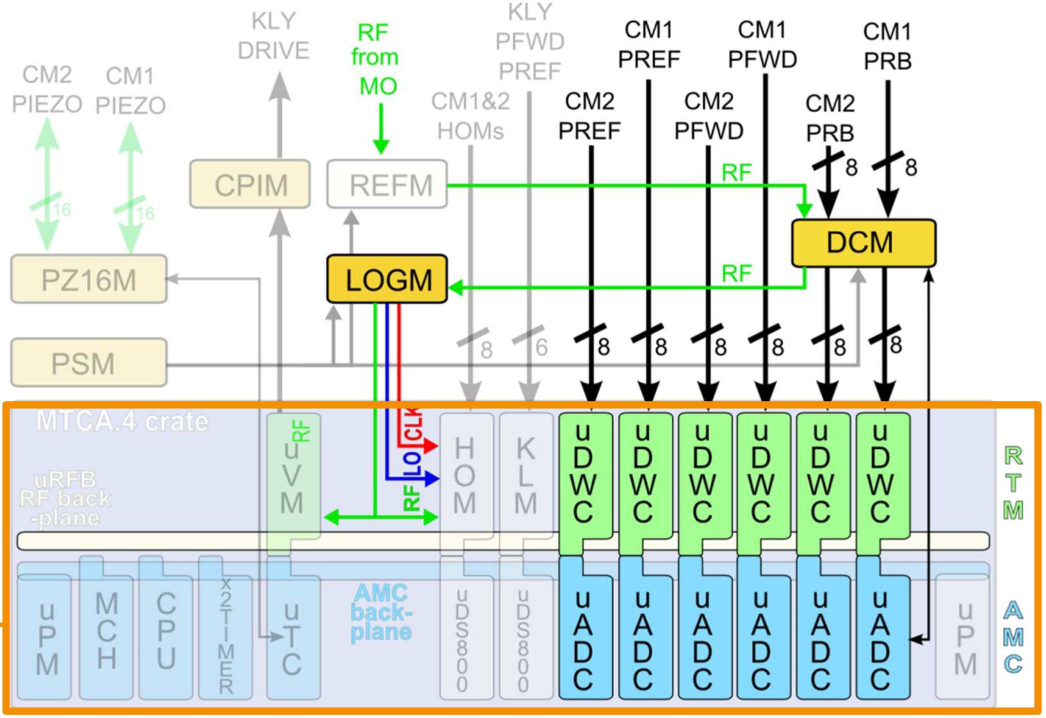


2 AMC / RTM Zone: IF Detection for Cavity Field Regulation



- XFEL 48-channel LLRF station:





- MTCA.4 incl. complete suite: LLRF/Diag./ Interlocks/HOM

Challenges:

- Total: 27 RF station / 800 cavities / >3000 RF signals
- Stability requirements < 0.01% & 0.01deg (<10fs)

2 Signal Conditioning and Digital Processing

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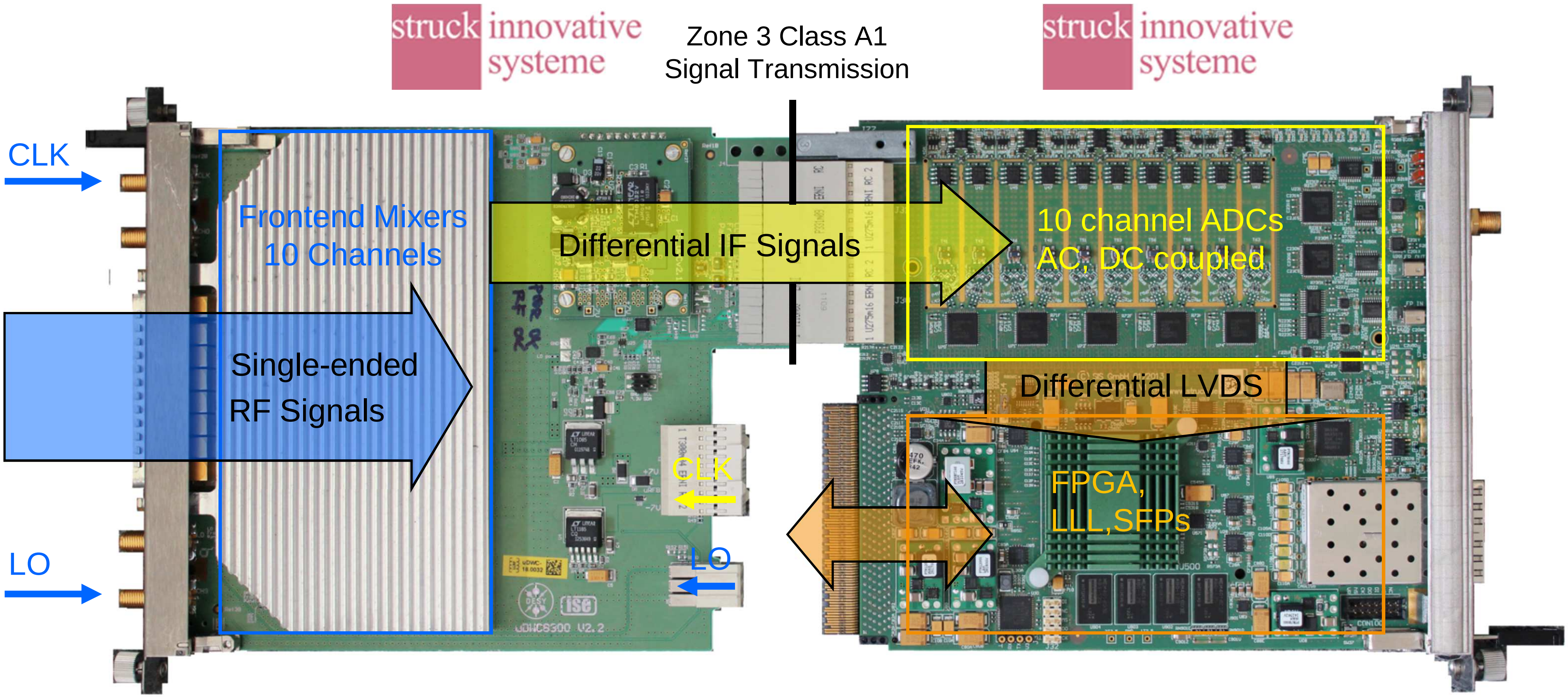
- High frequency Down-Converter
  (DRTM-DWC10, under license)
- Multi-Channel fast ADC Digitizer
  (SIS8300L2)



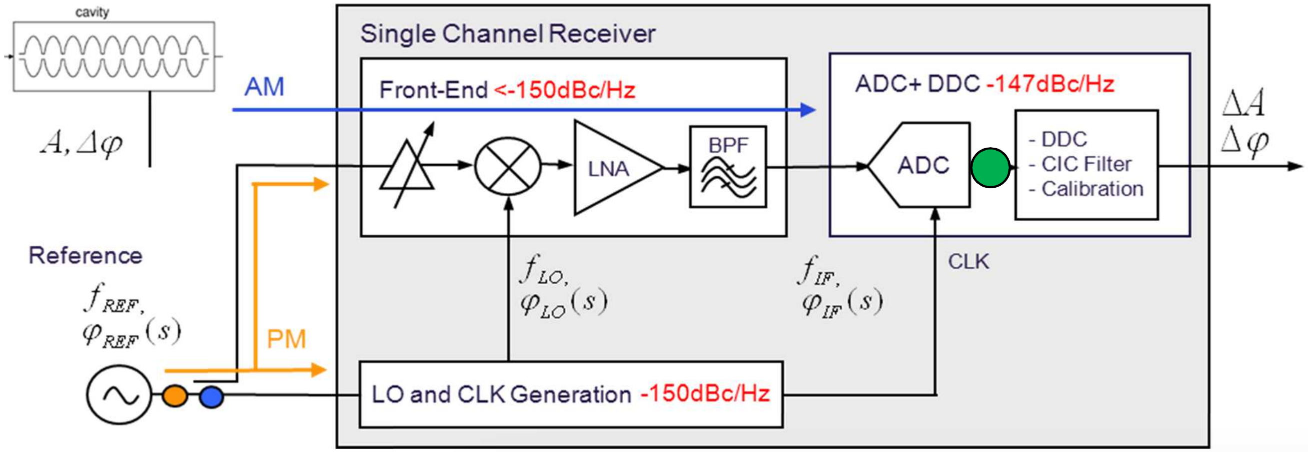
- 10 channel field detection
- S-band (700MHz - 4.0GHz)
- Resolution, 0.003%, < 10fs

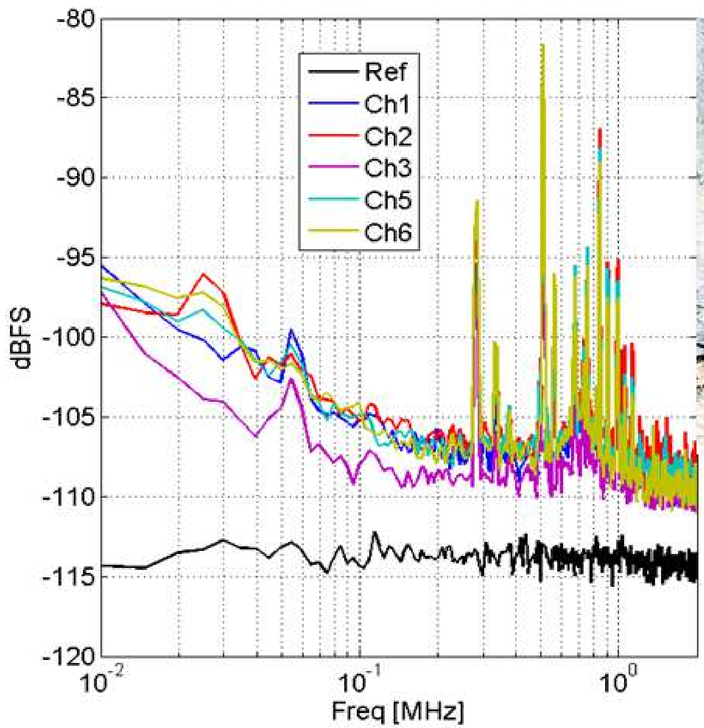
- 10 channel ADCs (125Msps, 16-Bits)
- FPGA (Virtex6) pre-processing partial cavity vectors
- Low latency links via MTCA-backplane

2 LLRF-Systems: Channel performance

- Spectral purity : (1DUT)

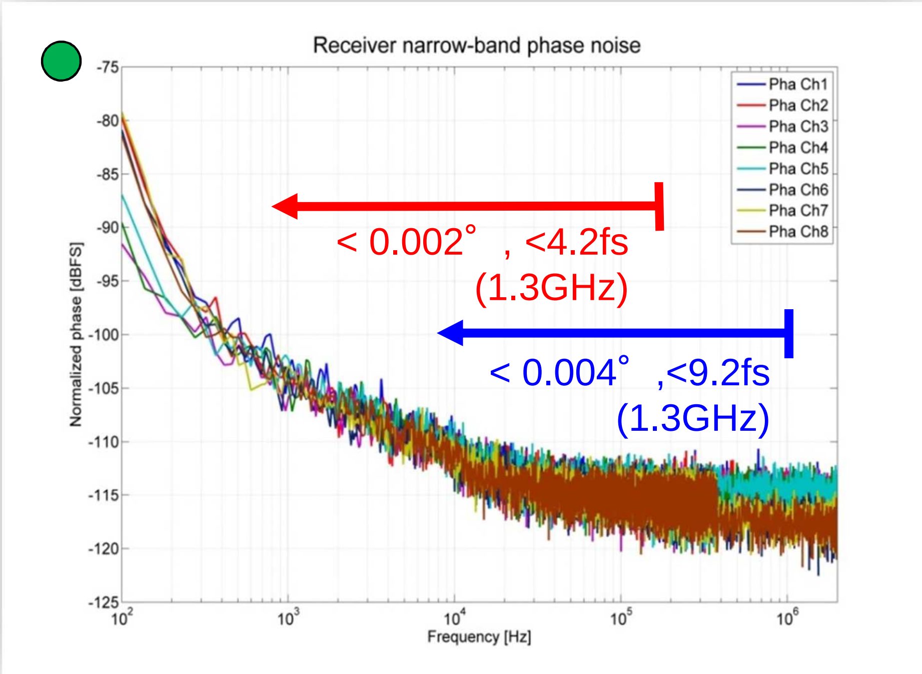
System's Fingerprint





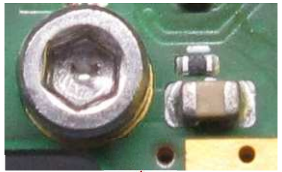
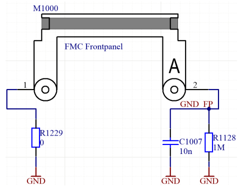
Spur removed on active and ground side (EMC)

Several years of group work!



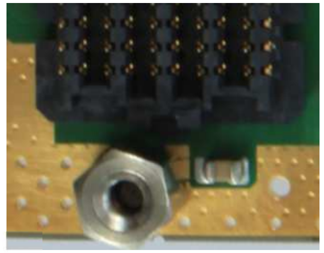
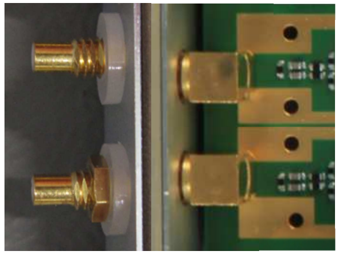
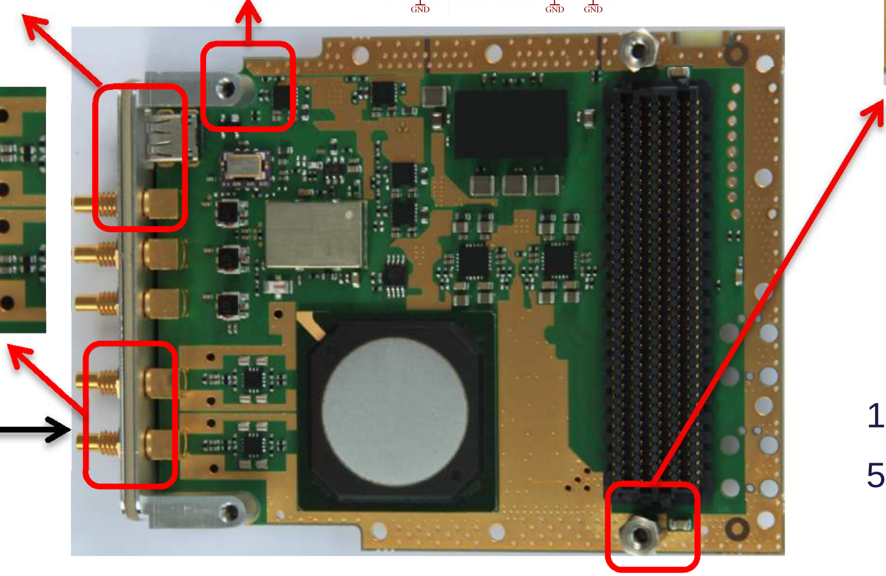
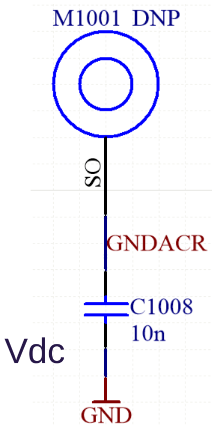
2 AMC / FMC Zone: Coarse Bunch-Arrival Time Monitor

- DFMC-DS500
  - direct sampling digitizer
  - 12 bits, 0.5 - 1 GSP/s
  - ADC 2.7 GHz @ 3dB
  - SE → DIFF
    Amplifiers (4.8 GHz)

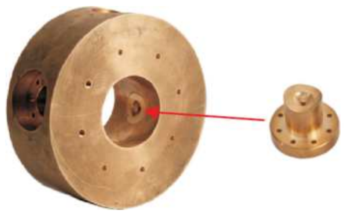
10n, 500 Vdc

1MΩ

10n

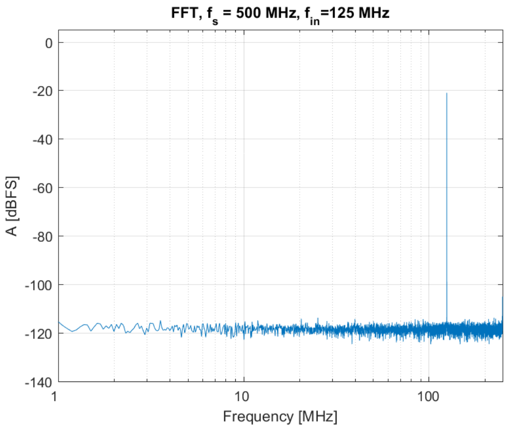
500 Vdc



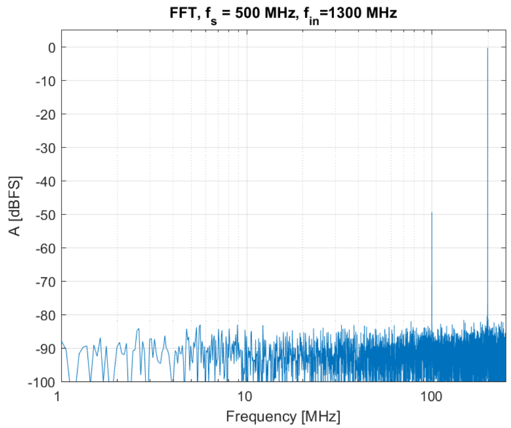
beam pick-up for CBAM

CBAM analog front-end

- Front panel has no direct connection to GND
- hexagon stand-off no direct connection between carrier GND and mezzanine GND
- RF connector GND is isolated from front panel



- f_s = 500 MHz, f_{in} = 125 MHz
- FFT: mean of 100 x 8000 samples



- f_s = 500 MHz, f_{in} = 1.3 GHz
- FFT: 8000 samples

Courtesy of J. Zink

3 MicroTCA.4 Signal-Integrity below <-80dB

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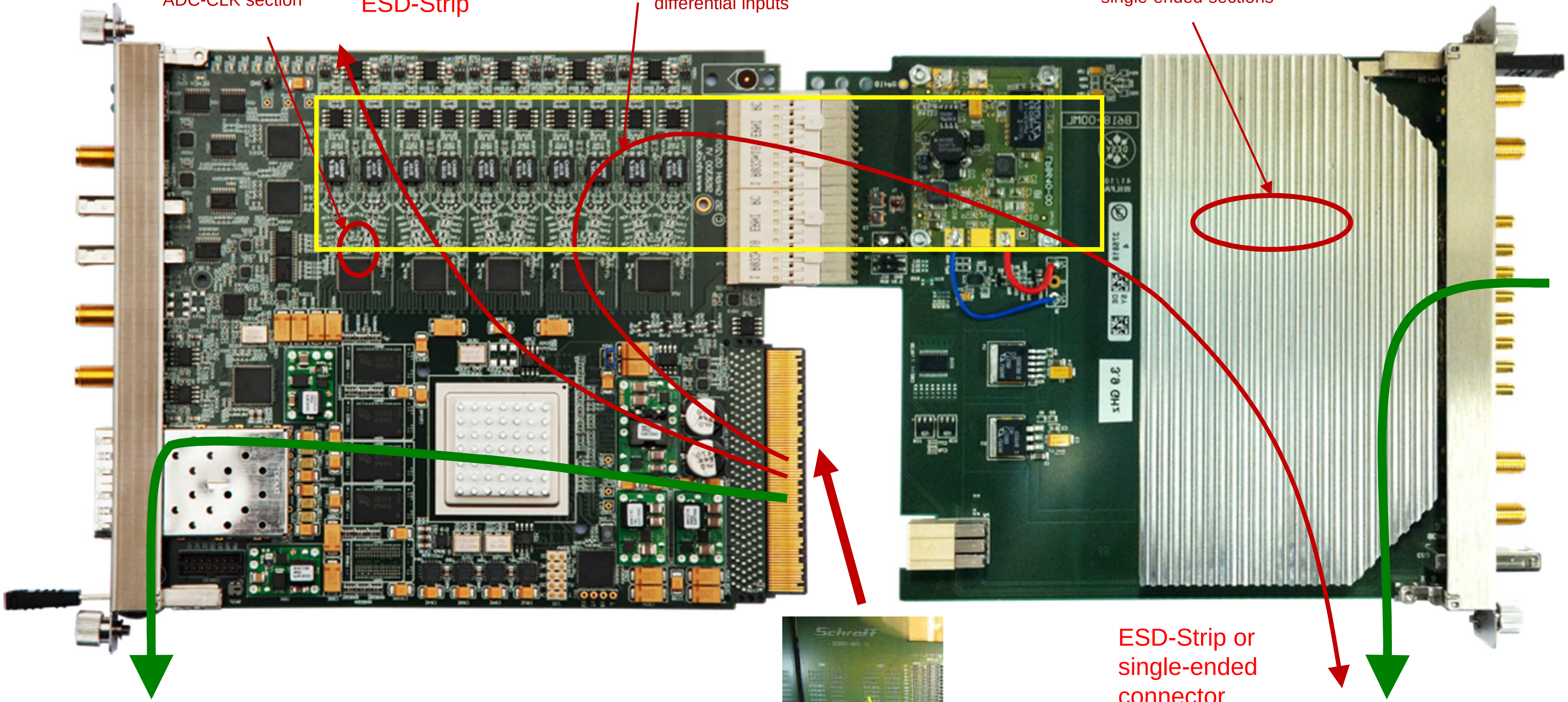
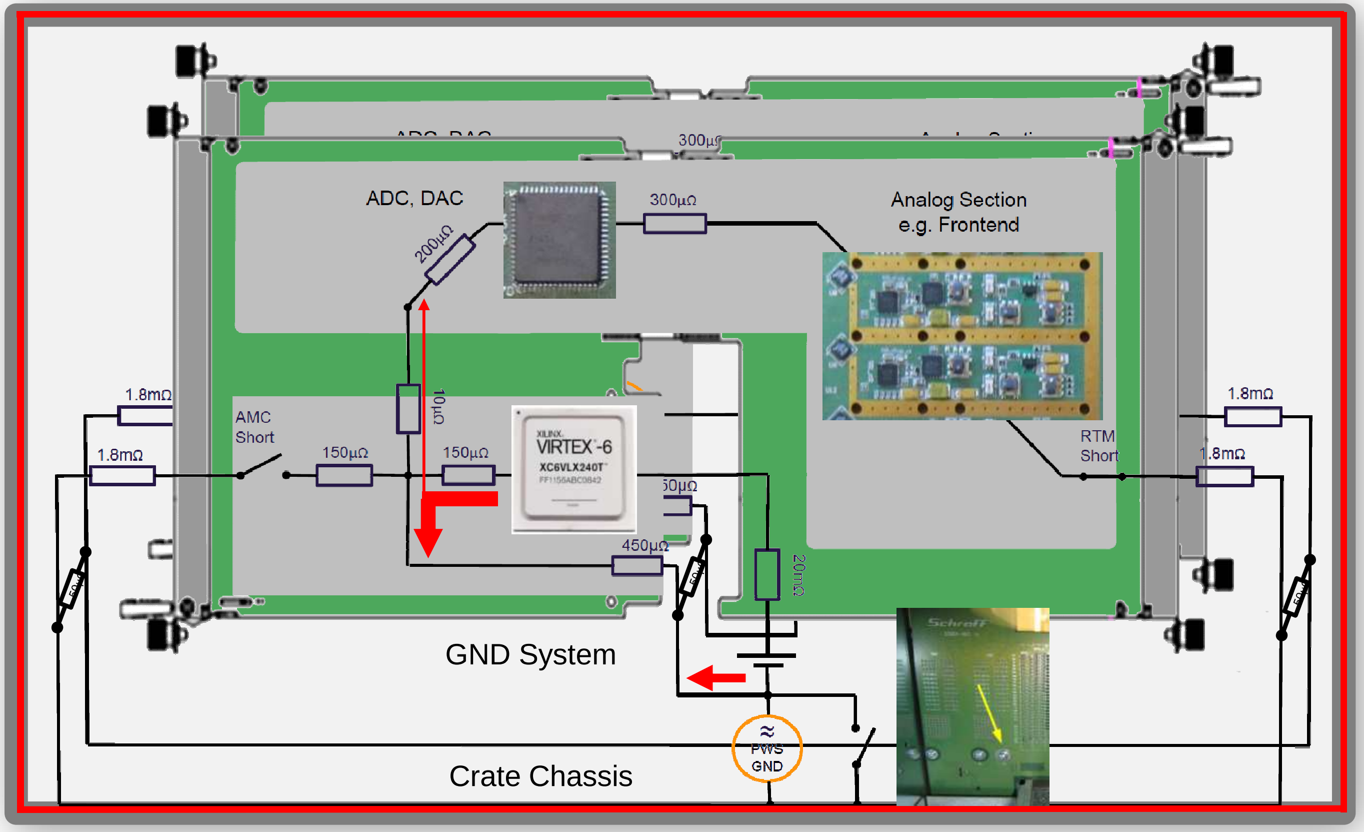
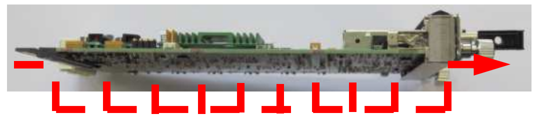
- Distortions current paths and its reduction :



- Properties of the Ground System in MicroTCA.4 for Z3 analog transmission:
  - Return currents and signals share the same ground, all slots share one ground.
  - Available shorts: Chassis-to-Ground (MicroTCA.4), Chassis-to-AMC, Chassis-RTM.
  - No bypass structures for boards, the ground is unshielded.





(No Bypass for the Ground)

Main distortions sources:

- AMC,RTM Loads

- Power Supply Module

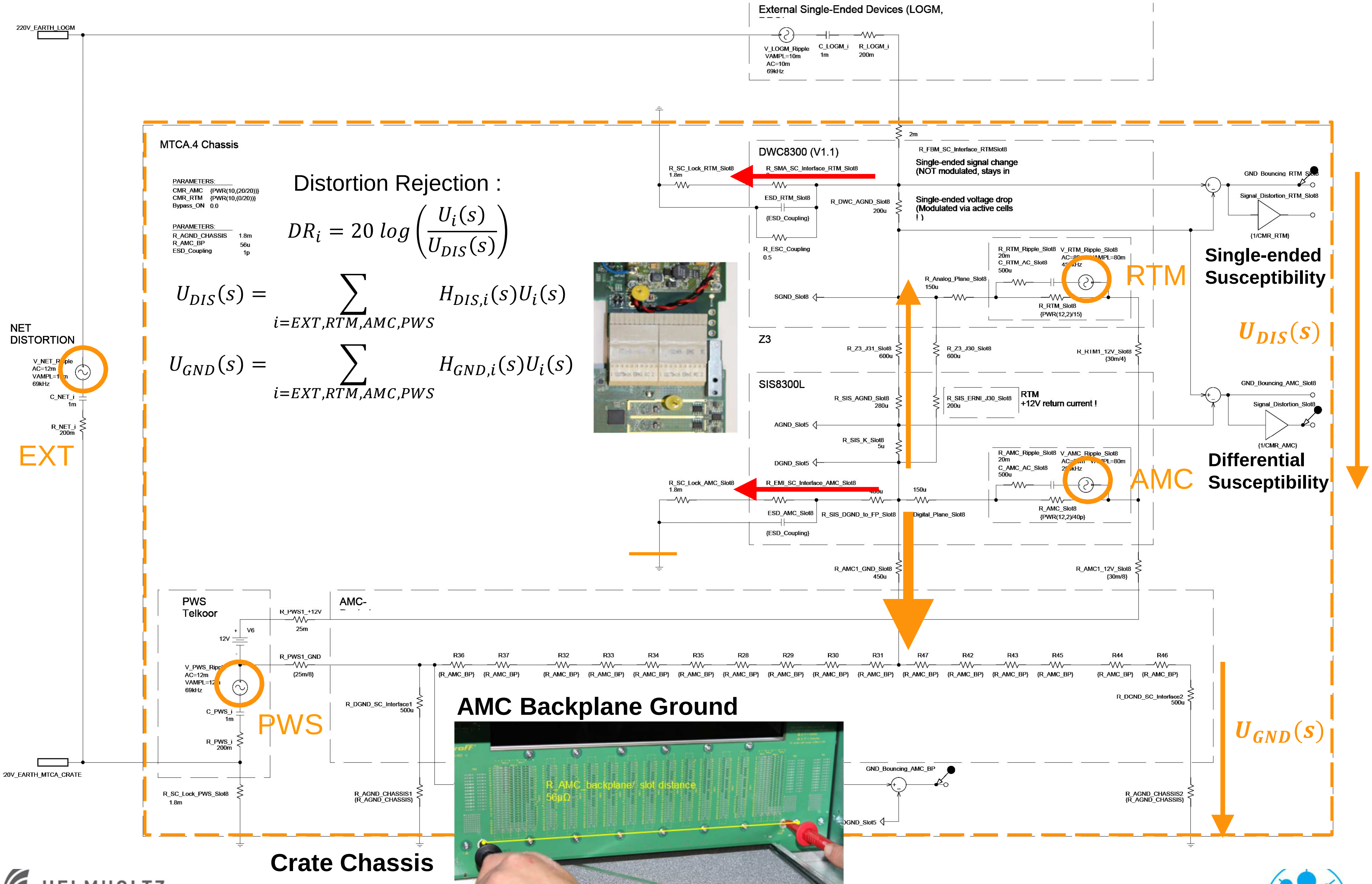
4 Crate Ground Modelling

Distortion Rejection :

$$DR_i = 20\,log\left(\frac{U_i(s)}{U_{DIS}(s)}\right)$$

$$U_{DIS}(s) = \sum_{i=EXT,RTM,AMC,PWS} H_{DIS,i}(s)U_i(s)$$

$$U_{GND}(s) = \sum_{i=EXT,RTM,AMC,PWS} H_{GND,i}(s)U_i(s)$$



5 EMC Optimization

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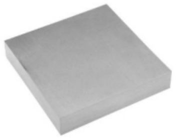
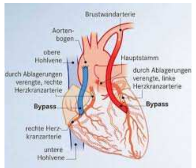
Improved local AMC, RTM ripples (active side)
approx. 10...20dB

Reduction of power-supply ground-chassis distortions
approx. 10…20dB



Improved the ground by return current redistribution
approx. 10...20dB

Short ground-chassis distortions of the power supplies
approx. 10dB

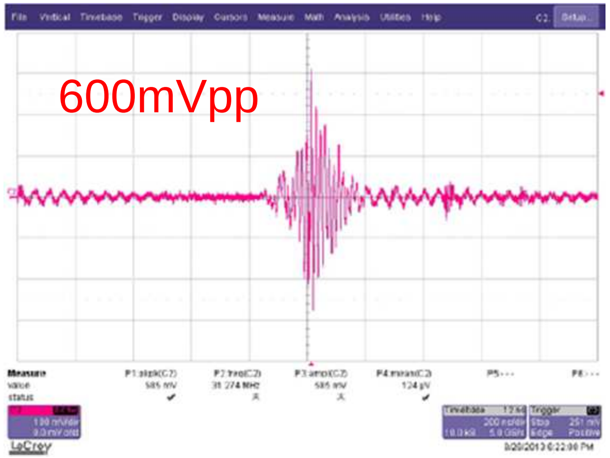


Bypass AMC, RTM ground distortions into the chassis
approx. 10dB

Improved the receivers CMR (project specific)
approx. 10dB

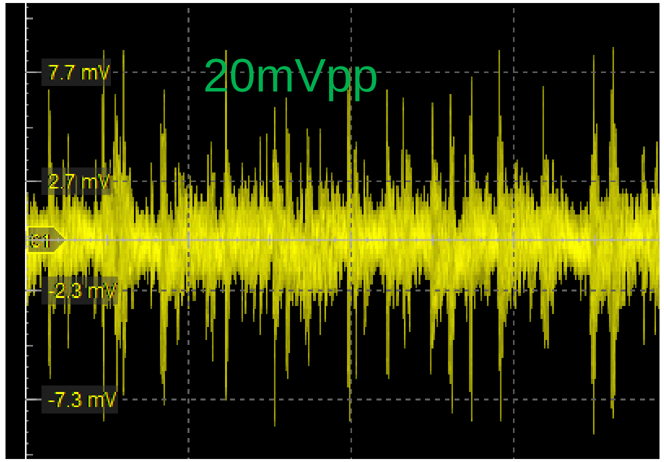
5 EMC Optimization

- Reduction of source ground-chassis distortions of the power supplies



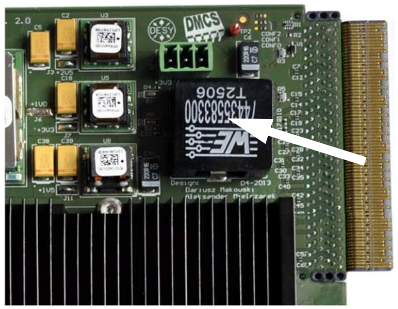
2011, MicroTCA.4 1kW Power Supply

Reduction of about 30



2014, MicroTCA.4 1kW Power Supply

- Reduction of AMC return ripples, Improved local AMC, RTM filter chains



LC-filter |-> DC/DC -> 1.LDO(s) -> LC-filter |-> 2. LDO (local) -> RF-filter -> analog section 1
| |-> 2. LDO (local) -> RF-filter -> analog section 2 …
|-> DC/DC -> 1.LDO(s) ---------------------------------------> RF-filter -> digital section 1
|-> DC/DC -> 1.LDO(s) ---------------------------------------> RF-filter -> digital section 2 …

- Reduction of AMC return ripples
- Decoupling of AMC modules +12V

Reduction of
- DC/DC chopper lines,
- Distortions and noise

LDO : LF noise reduction <1MHz
RF-filter : RF noise reduction >1MHz
for ADCs, ultra-low clock jitter etc.

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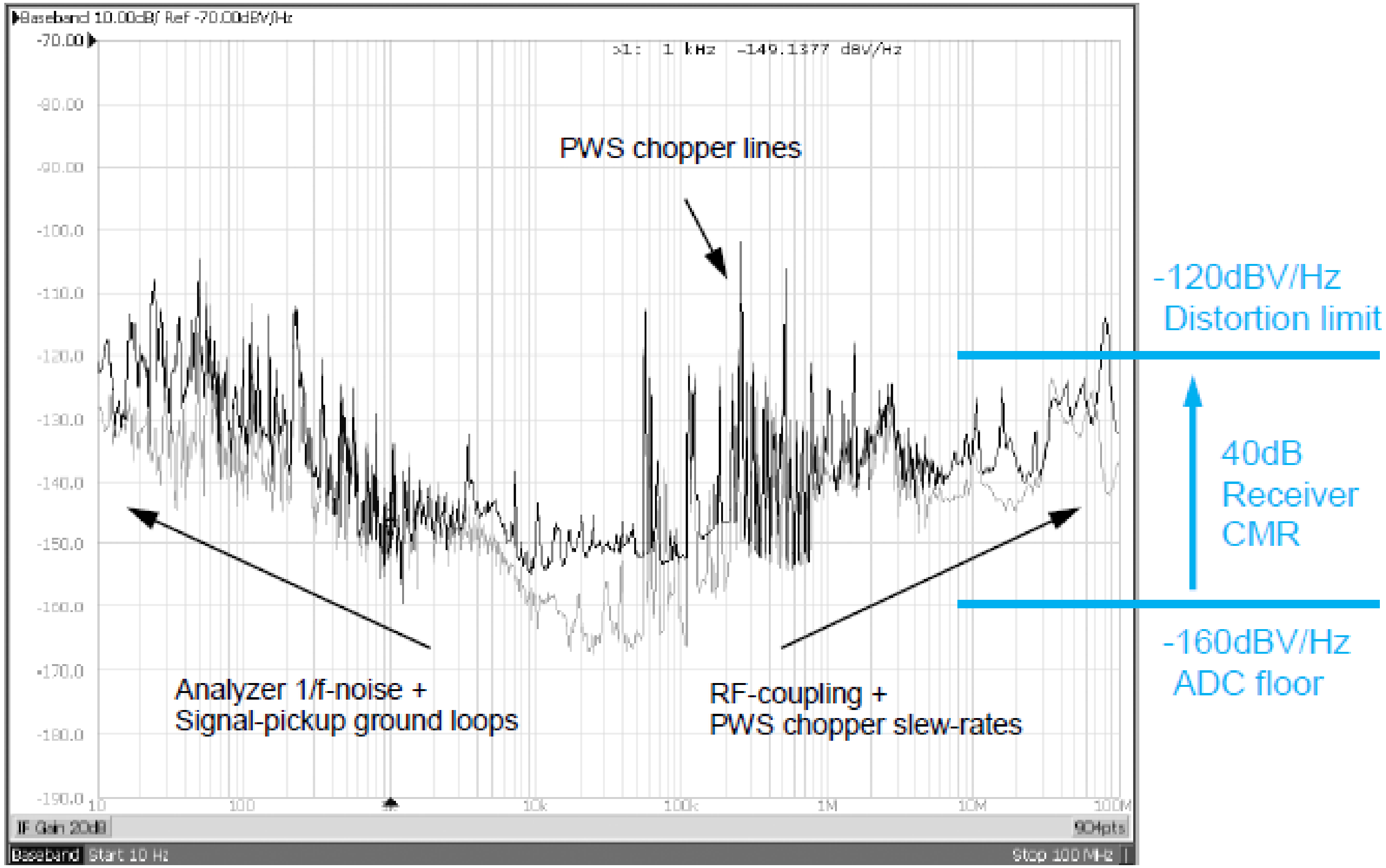
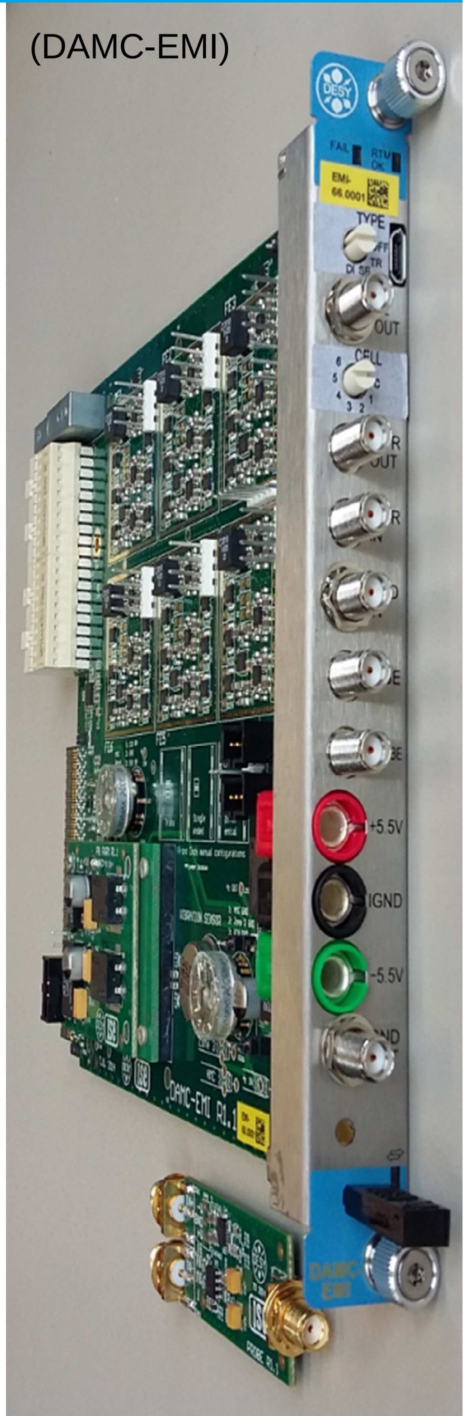
Measuring the Ground-Chassis Distortions

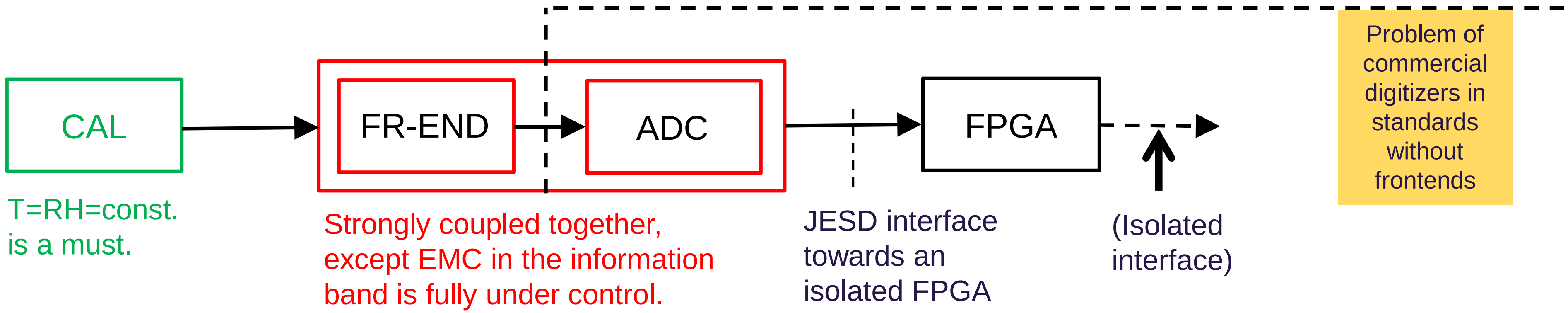




DAMC-EMI Functions:

- Ground-to-Chassis measurements
- Power supplies measurements
- Voltage ground prober
- Vibrations measurements
- Ground influences from RTMs

5 System Partitioning / Packaging for < -80dB Stability



High frequency Applications	MicroTCA.4 Configuration	AMC: ADC ext. : FR-END	AMC or RTM: ● FR-END + ADC	AMC: ADC ● RTM: FR-END	Proprietary
	Signal integrity by external disortions	Depend on EMC	Good, Excellent for optical inputs	Good, Excellent for optical inputs	Excellent
	Signal integrity by internal distortions	Very good	Very good	Good	Excellent
	Modularity	Excellent	Excellent	Excellent with Z3 Class	Poor

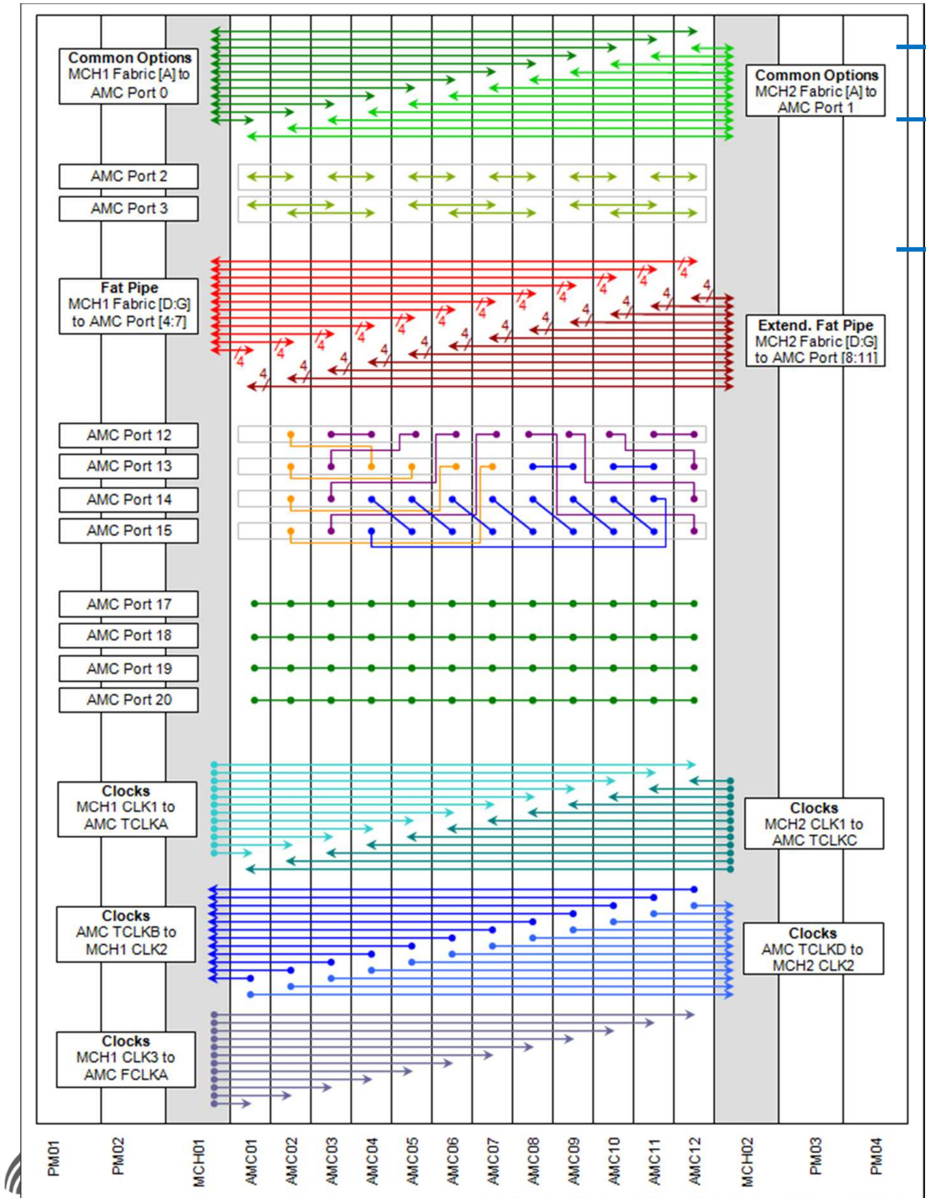
Baseband Applications	MicroTCA.4 Configuration	AMC: ADC ext. : FR-END	AMC or RTM: ● FR-END + ADC	AMC: ADC RTM: FR-END	Proprietary
	Signal integrity by external disortions	Depend on EMC (strongly)	Depend on EMC, Excellent for optical inputs	Depend on EMC, Excellent for optical inputs	Excellent
	Signal integrity by internal distortions	Very good	Very good	open - to be tested	Excellent
	Modularity	Excellent	Excellent	Excellent with Z3 Class	Poor

● : adressed in this presenation

6 Future EMC Challenges : MicroTCA.4 digital Upgrades

FIL

MicroTCA.4 AMC Backplane Connections PCIe gen5 :



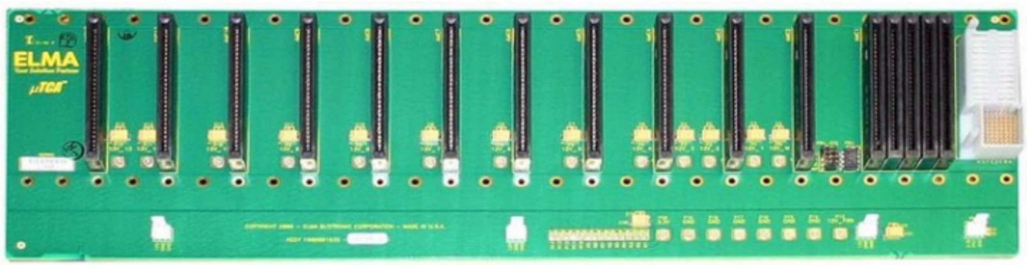
10Gbase-KR Ethernet

Slim-pipe support ≥20Gbps NRZ per lane

Update fat pipes to support 32Gbps NRZ (and **56Gbps PAM-4, 16GHz BW**) per lane minimum (PCIe gen5, 200Gbase-KR4).

EMC related tasks :

- MTCA backplane connector crosstalk tests
- Impact of moving MCH to the center to reduce channel length will be evaluated
- Payload power per slot to 240W with better isolation
- Ground-Chassis-Distortion to be improved by -20dB
- Verification with next generation receivers



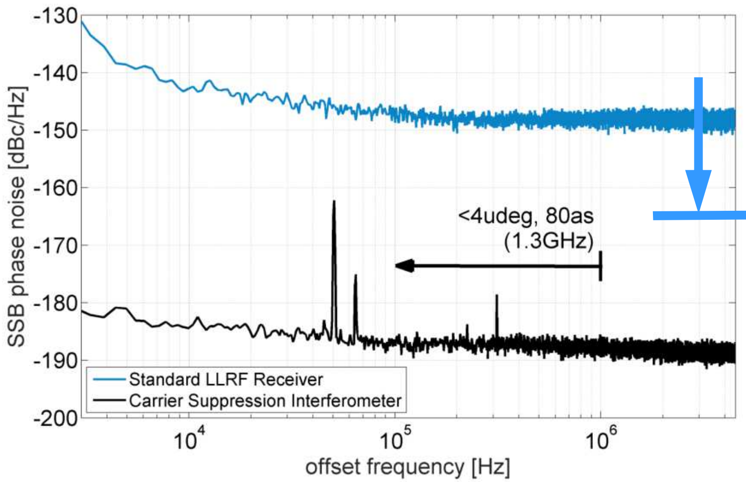
6 Future EMC Challenges : MicroTCA.4 Receiver Roadmap

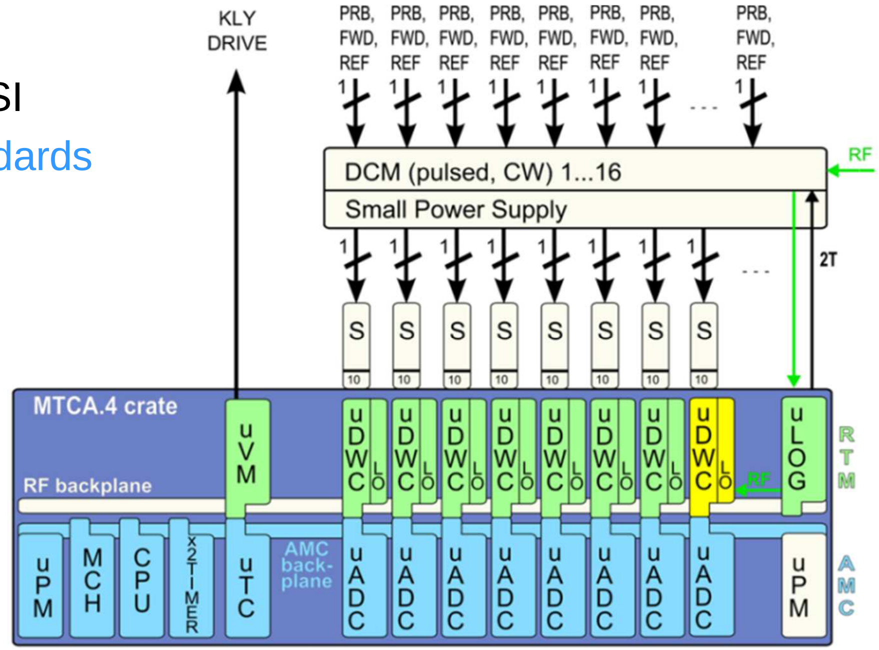
FIL

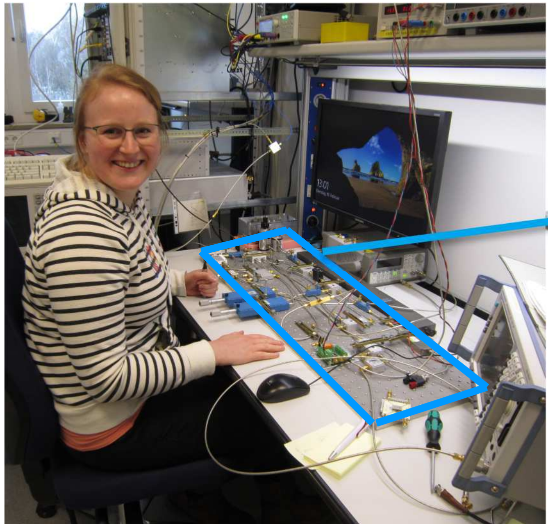
- Improvement of Ground-Chassis Distortion by -20dB :

Receiver Improvements (<1fs, <100as, SRF):

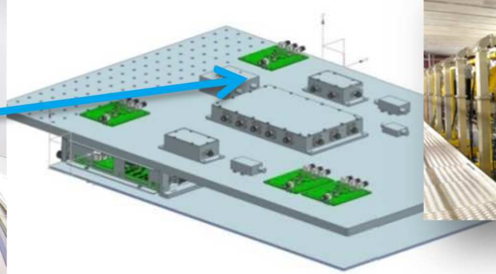
- → Non-IQ detector in a hybrid configuration with a CSI
- → Brute-force ADC or channel parallelization in Standards

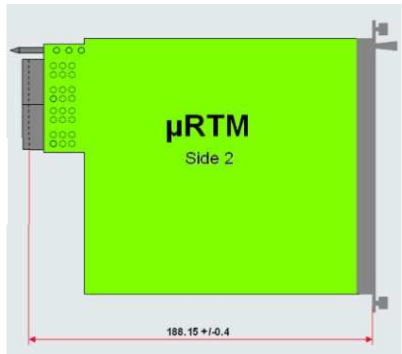






- High-Q_L Cavity CW-Operation: at CMTB (DESY)





Courtesy of L.Springer

2020

2025?

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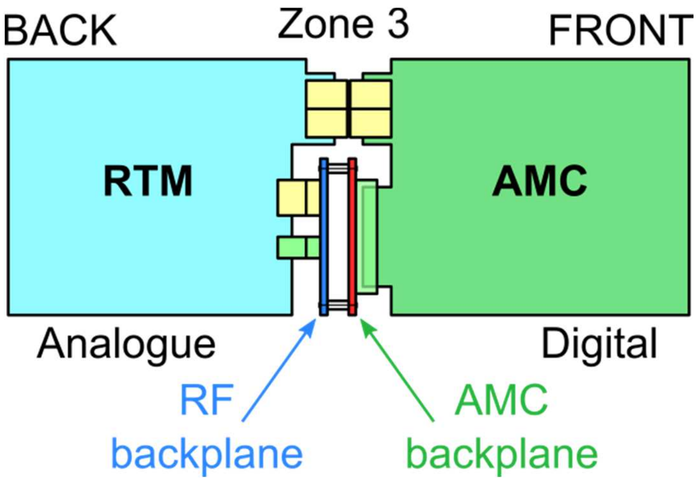
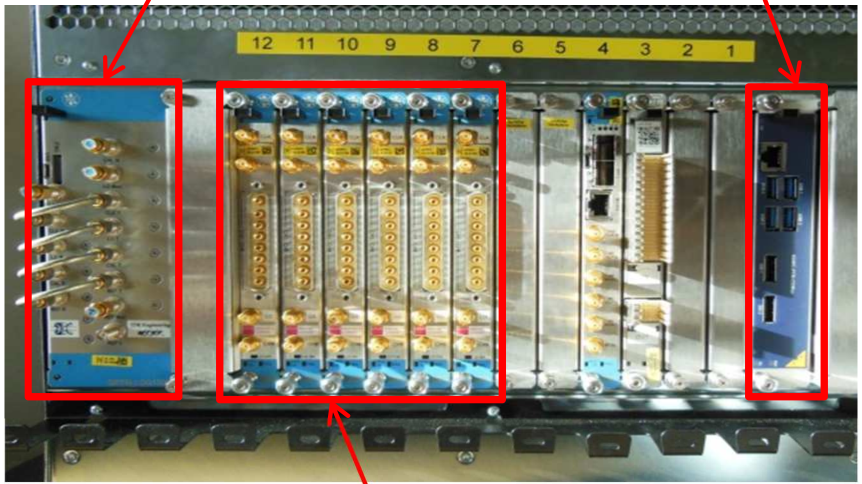
Thanks for your attention!

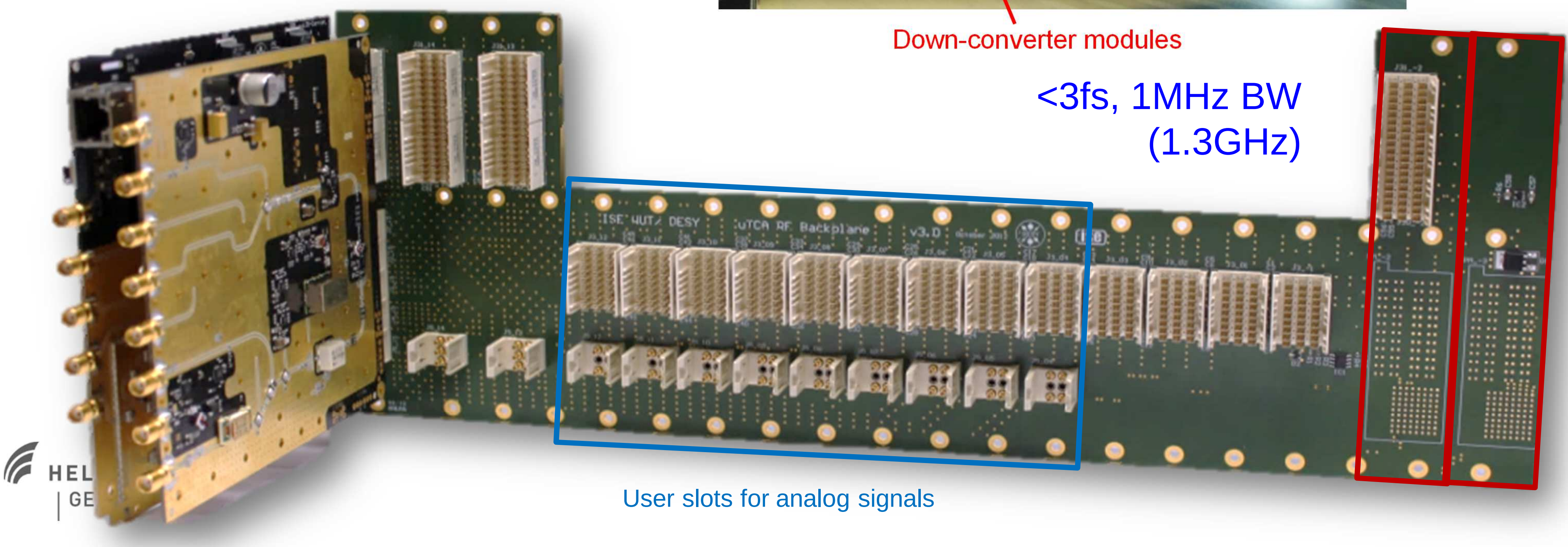
- Low-impedance bypass managed RF-Backplane



This avoids a complicated cable management.



<3fs, 1MHz BW
(1.3GHz)



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Content