‚Long-term stability improvement tests of ACC1 – first results –'

Frank Ludwig – DESY,
Matthias Hoffmann – PSI

C. Gerth, K. Hacker, M. Hoffmann, W. Jalmuzna, F.Ludwig, G. Möller, P. Morozov, C. Schmidt

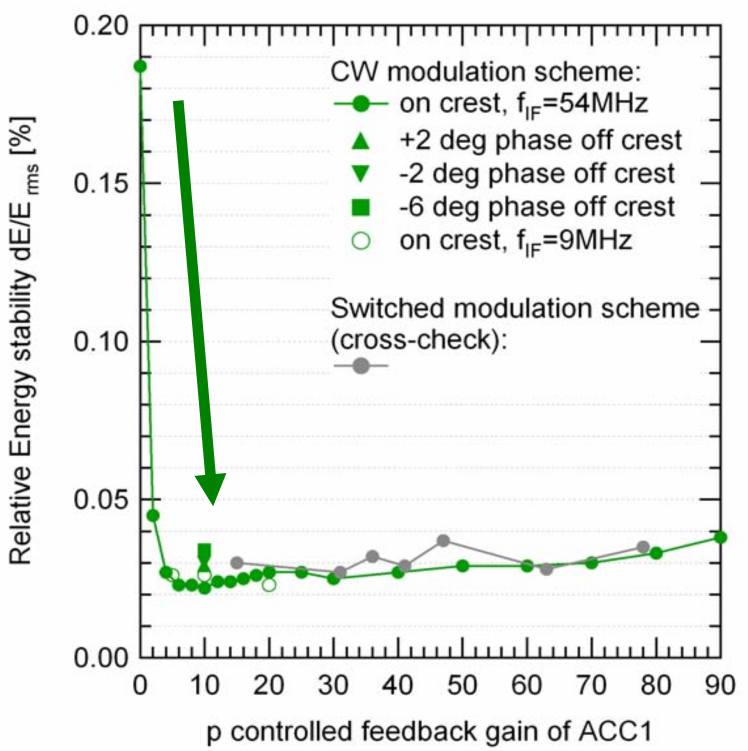
for the LLRF-Team

Content :

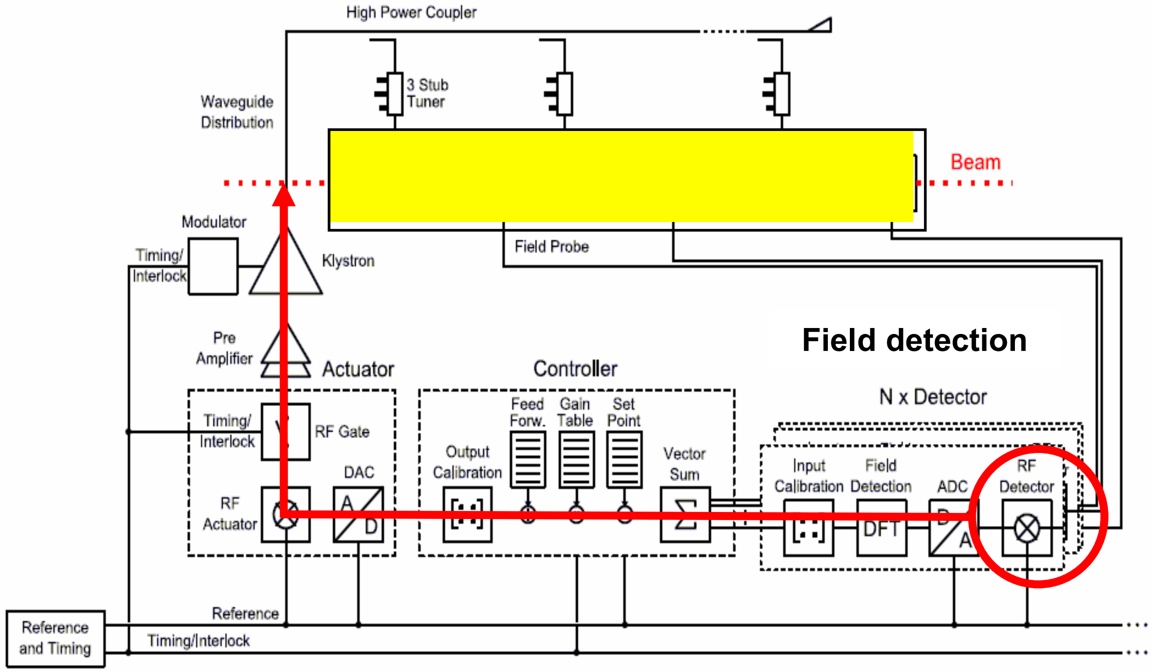
- Motivation – long-term Instabilities
- Reference Tracking & Injection Lab Performance
- Reference Injection under Test at FLASH
- Outlook

Robust machine operation

- Pulse-to-Pulse Beam Stability :



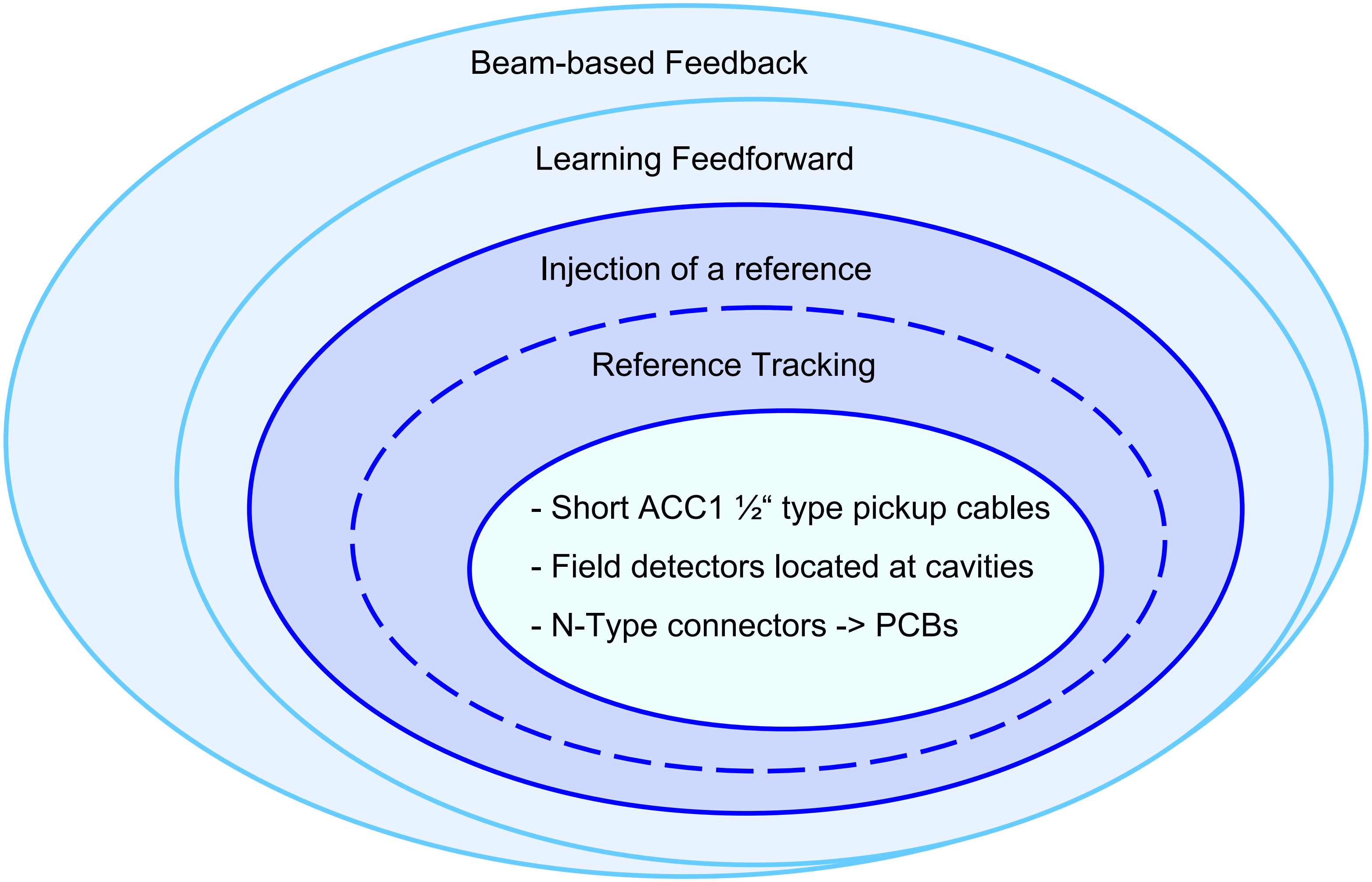
- Long-term Cavity Field Regulation



Drifts from Field Detector are amplified and pushed onto the beam.

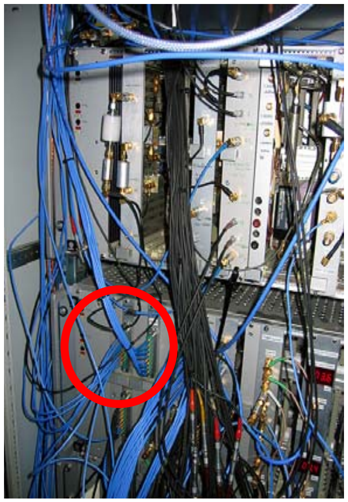
Drifts ⟶ SASE Instabilities

- Proposal for a robust long-term stable machine operation :

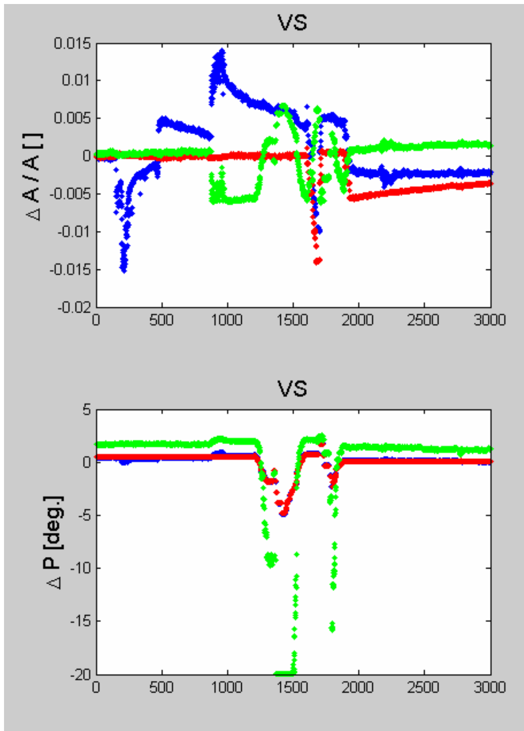


Examples of long-term Instabilities

- ACC1 pickup-cable vibrations :

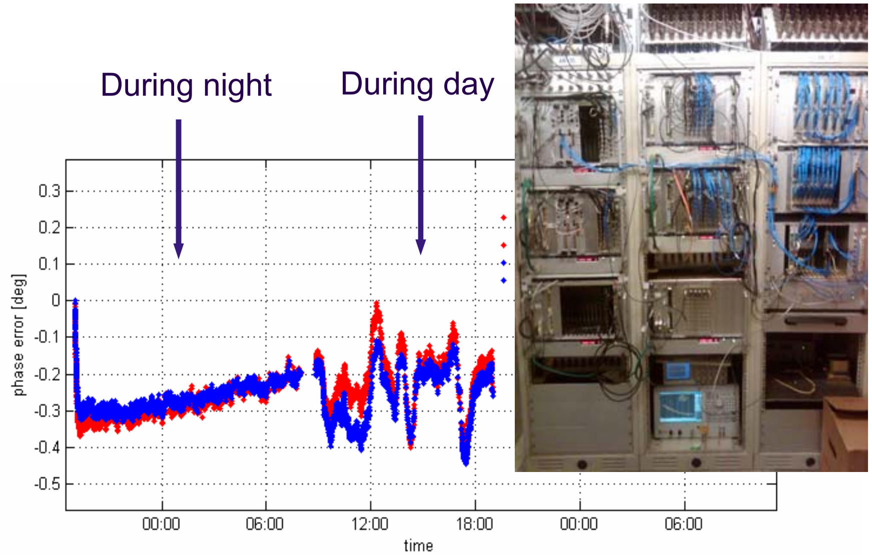


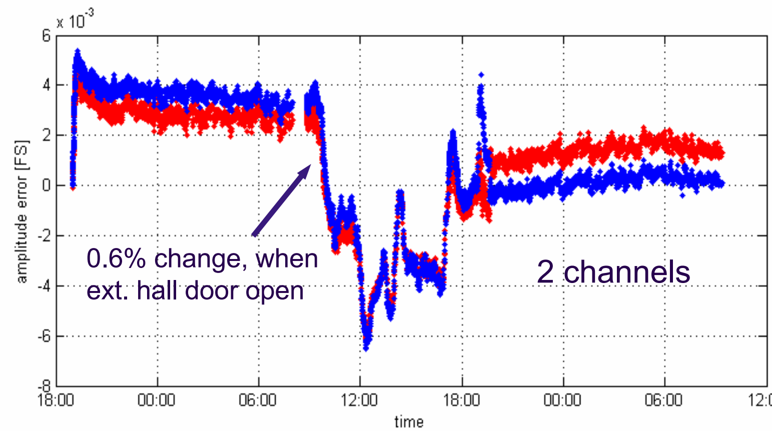
ACC1-LLRF-System



Several degree vector sum phase changes

- ACC456 Ext. Hall 3 / Door open :

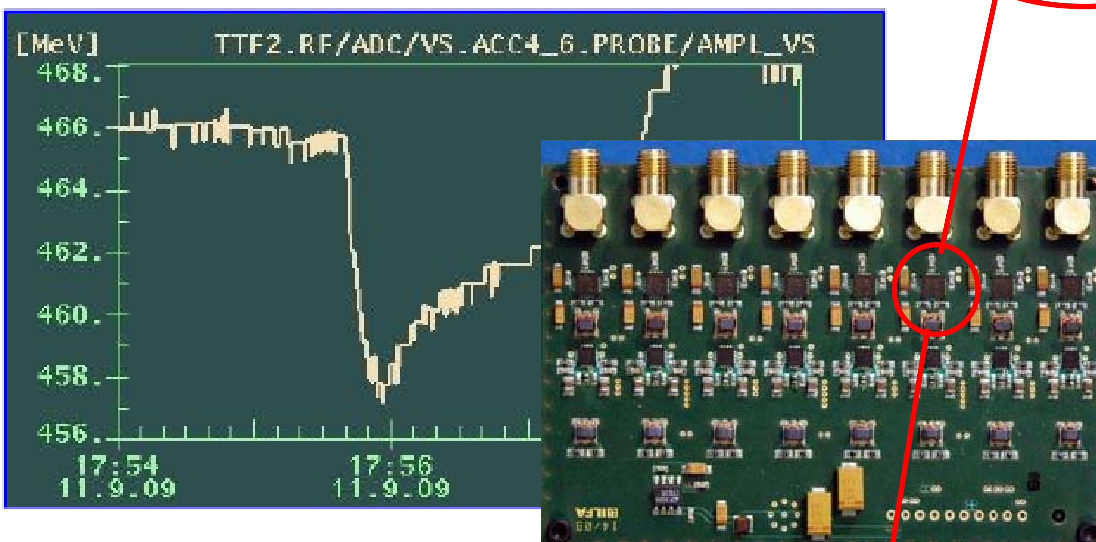




Examples of long-term Instabilities

- Field detectors / Front-end mixers:

Amplitude drift of vector-sum in ACC456 for 10 deg. C temperature change of downconverter
Temperature sensitivity of downconverter for amplitude is approximately 2e-3 / deg. C
Temperature change just before 17:56



Datasheet :

	RF = 1900MHz	2.3	dB
	RF = 2200MHz	2.0	dB
	RF = 2650MHz	1.8	dB
	RF = 3500MHz, IF = 380MHz	[illegible]	dB
Conversion Gain vs Temperature	T_A = −40°C to 85°C, RF = 1900MHz	−0.018	dB/°C
Input 3rd Order Intercept	RF = 450MHz, IF = 140MHz, High Side LO	23.2	dBm
	RF = 900MHz, IF = 140MHz	24.5	dBm
	RF = 1700MHz	24.2	dBm

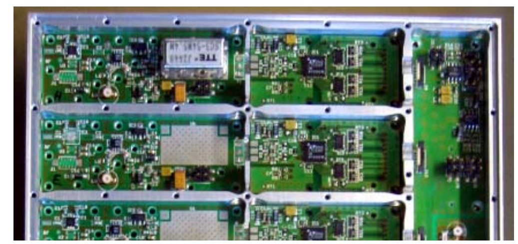
…we have a thermal problem...

- Receivers Worldwide :

Active multi-channel / DESY 2007 :

θ_A = 2e-3/°C, θ_P = 0.2°/°C

Passive multi-channel / DESY 2006 :



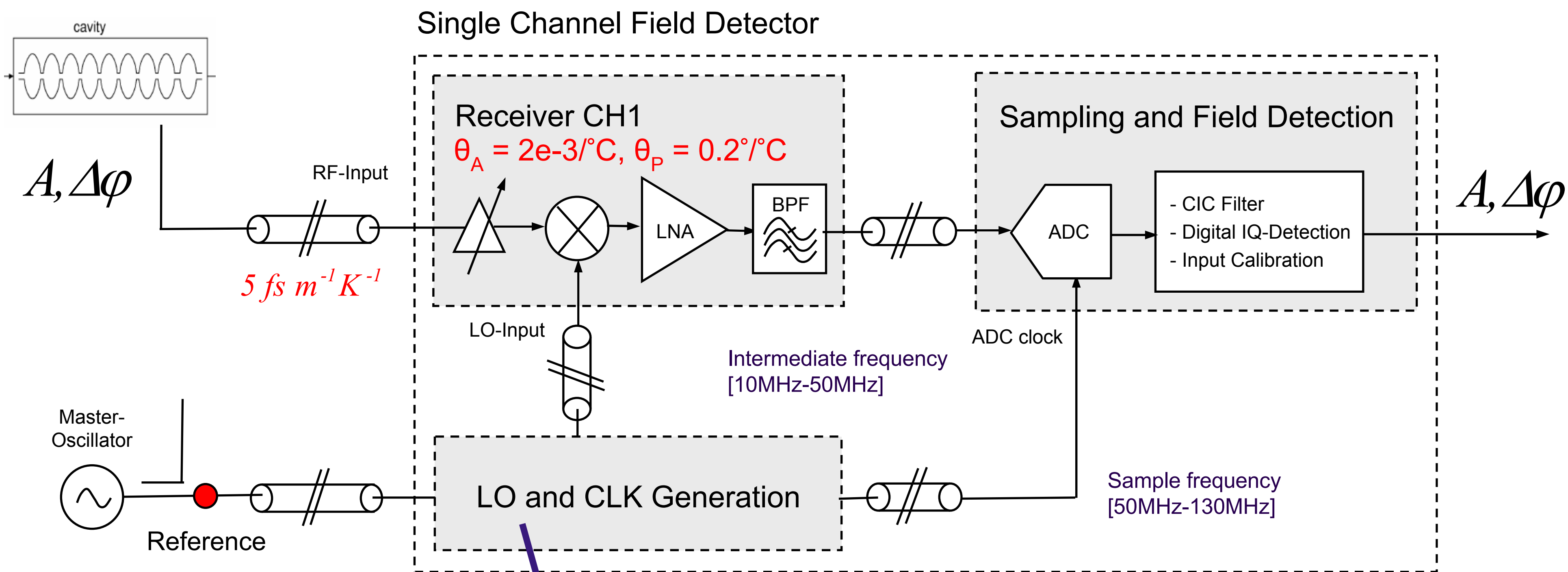
θ_A = 2e-3/°C, θ_P = 0.2°/°C

Passive multi-channel / FermiLab 2007 :

θ_A = 2e-3/°C, θ_P = 0.2°/°C

Field Detection long-term Instabilities

- Distributed down converters using the non-IQ-sampling scheme :



…cables, dividers, amplifiers, filters...

…hopeless in a distributed system...

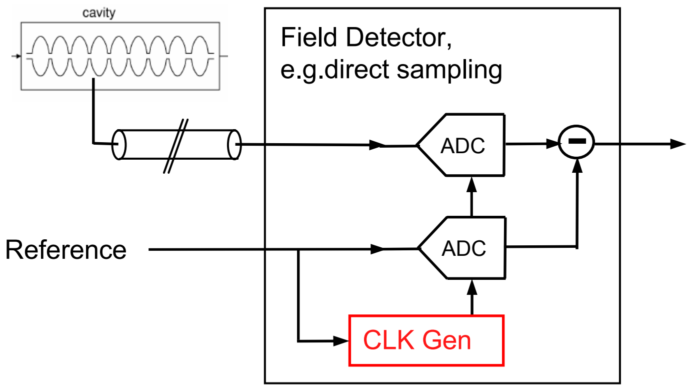
Robust machine operation

- Injector-Section : 0.01 $°C_{pp}$ -> 0.02% cavity amplitude stability,
  0.02° cavity phase stability
- Main-Section : 0.5 $°C_{pp}$ -> 0.1% cavity amplitude stability,
  0.1° cavity phase stability
- Field detector passive or active thermal stabilization
- Field detector passivation (humidity dependence)
- Automated drift calibration *
- Beam based feedbacks

* FNAL, LLRF Workshop 02/09/06 ‚Multichannel down-converters for the XFEL ‘, F.Ludwig, L.Doolittle et.al.

Principles of Drift Calibration

- **Reference Tracking :**

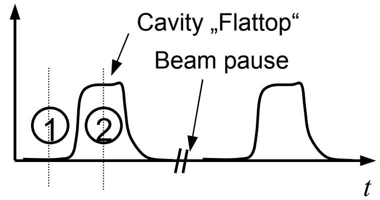


+ Demonstrated, e.g. with direct sampling
+/- Efficient only for symmetric receivers
+ Low amplitude drifts
- Supress only correlated noise

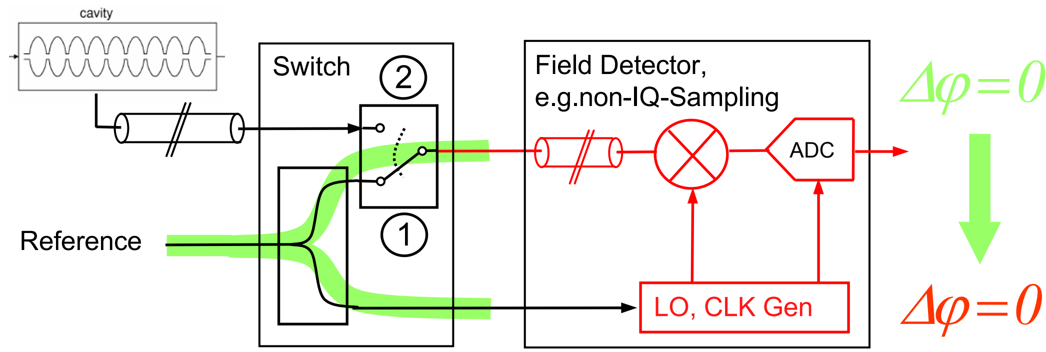
- **Reflection at the cavity :**

+ Compensates in addition antenna to cavity pickup

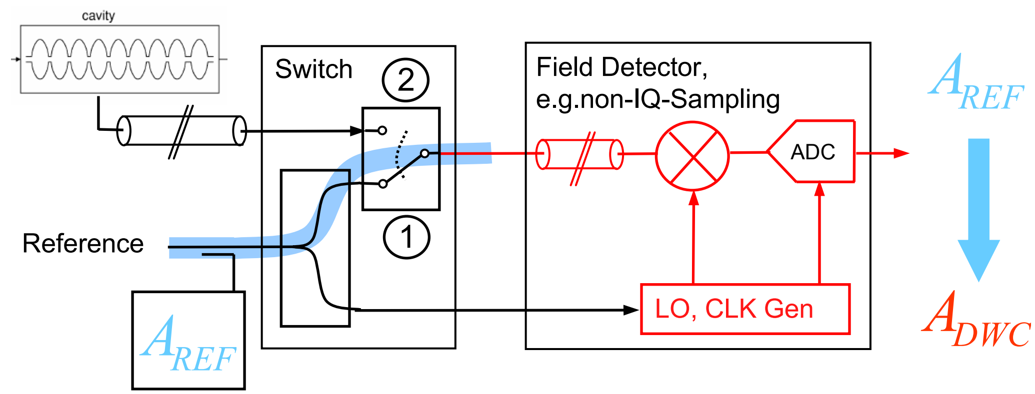
- **Reference Injection :**



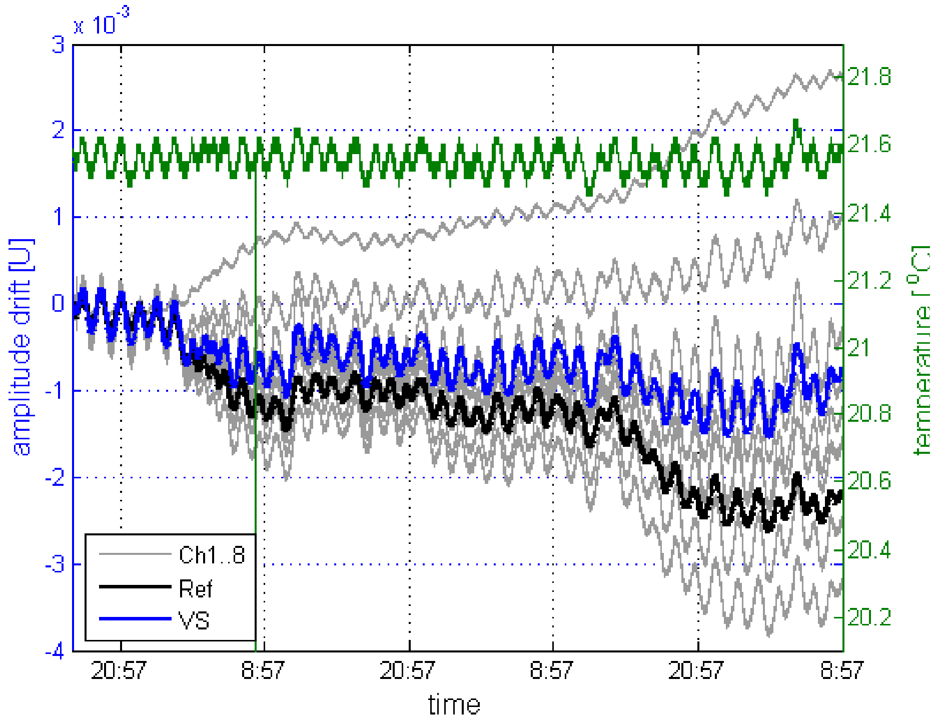
Relative Phase Calibration :



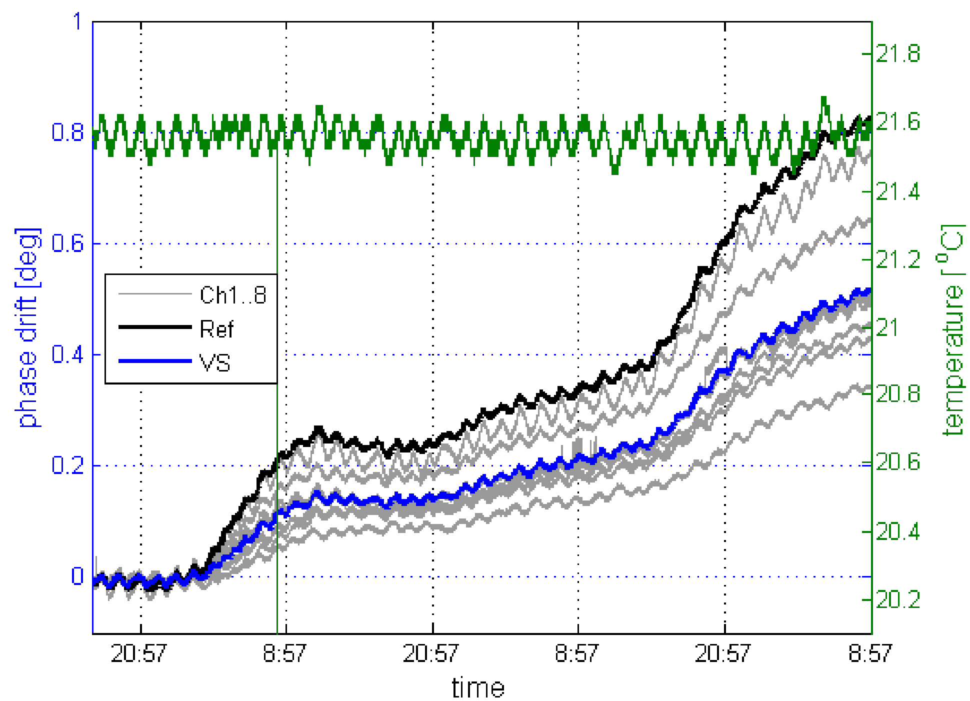
Absolute Amplitude Calibration :



- Amplitude Drift :



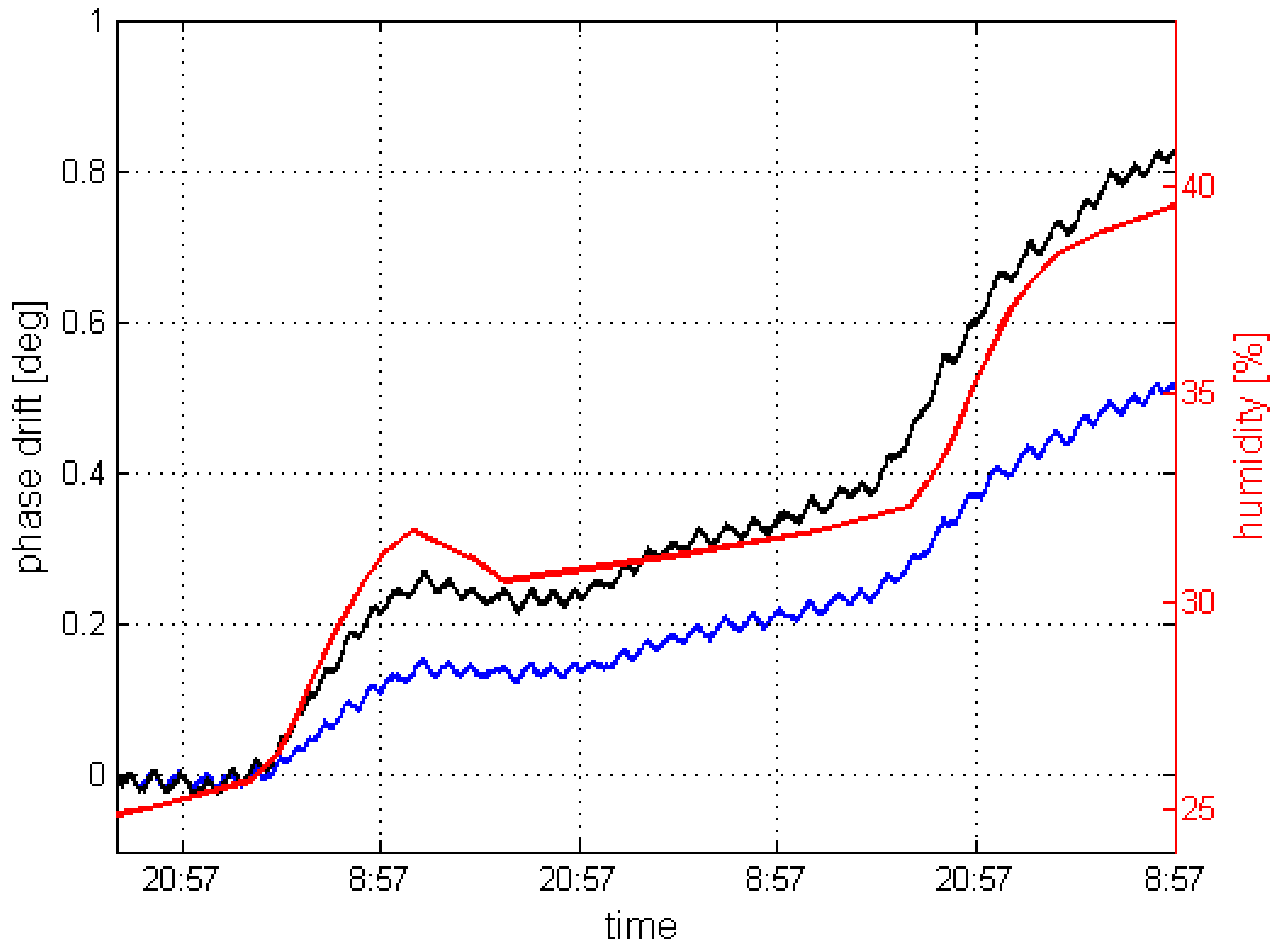
- Phase Drift :



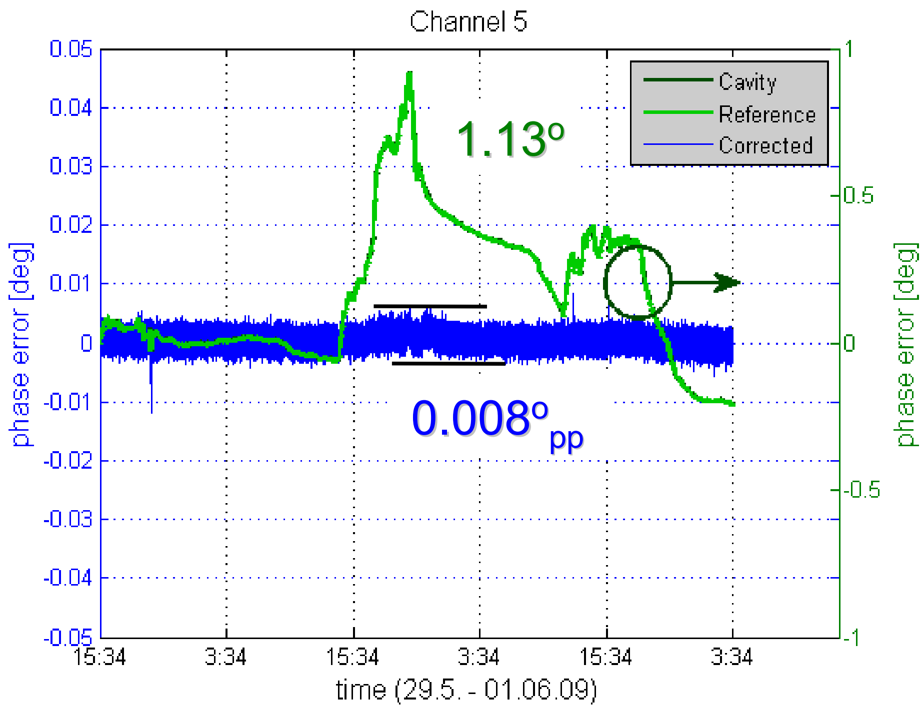
- Correlation between temperature and amplitude and phase drifts.
- Two effects are visible on amplitude and phase ...

Reference Tracking under Test in Lab

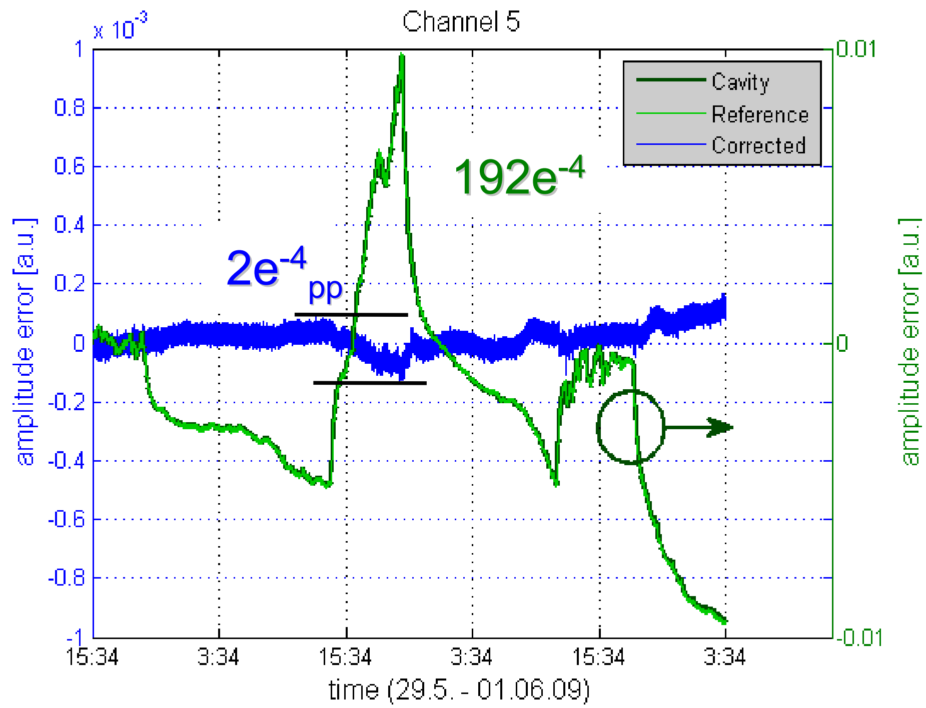
- Influence from Humidity :



- Phase Stability over 60h:

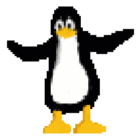


- Amplitude Stability over 60h:

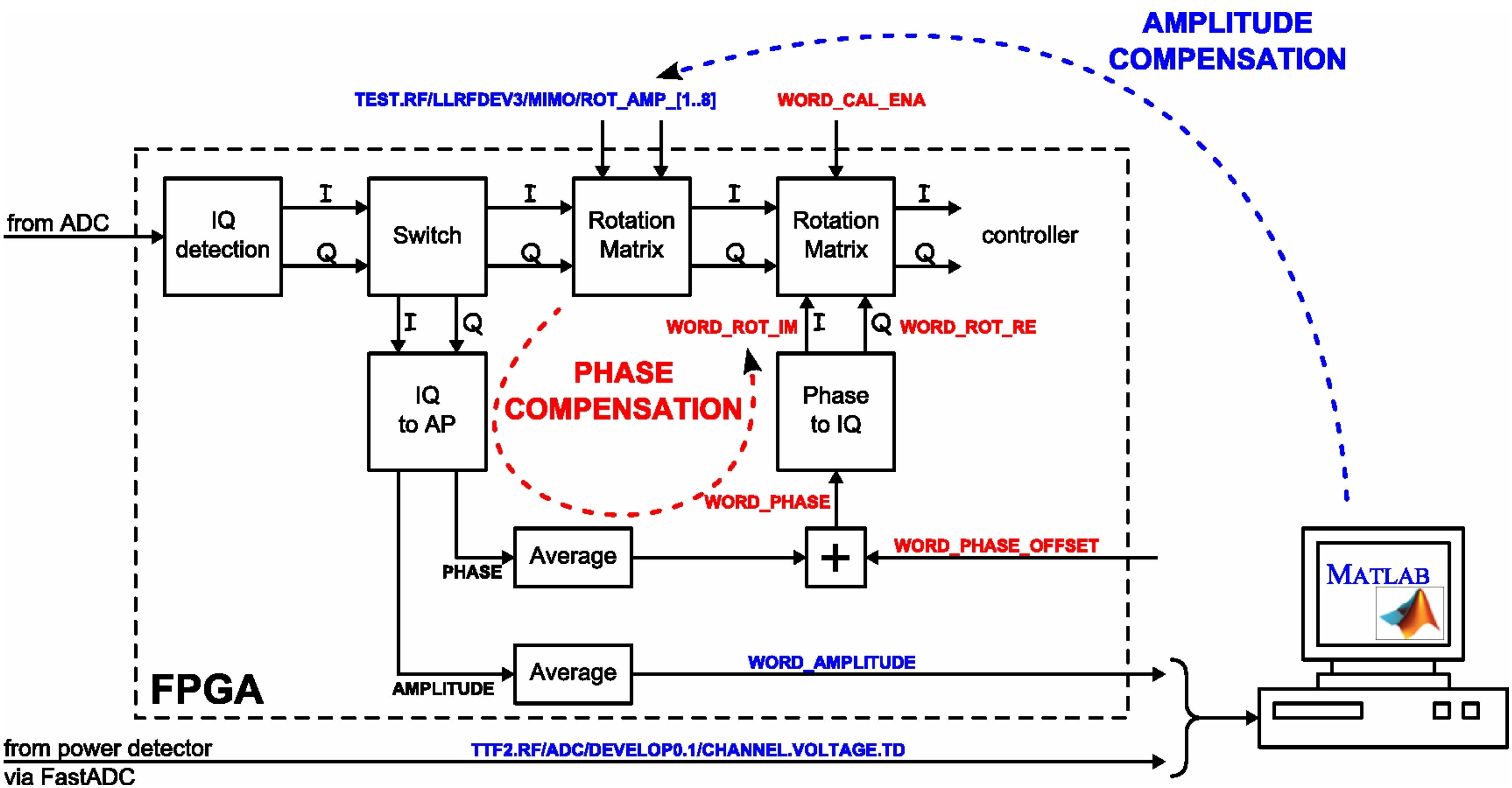


Compensation of phase drift : ~ 1/140

Compensation of amplitude drift : ~ 1/100

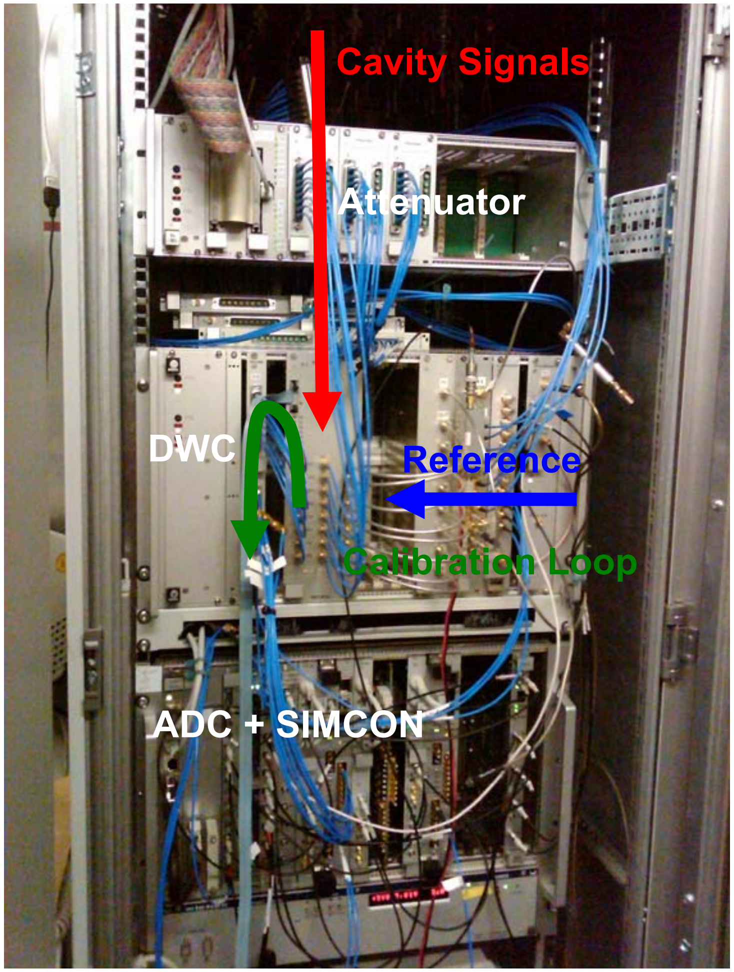


Reference Injection Algorithm

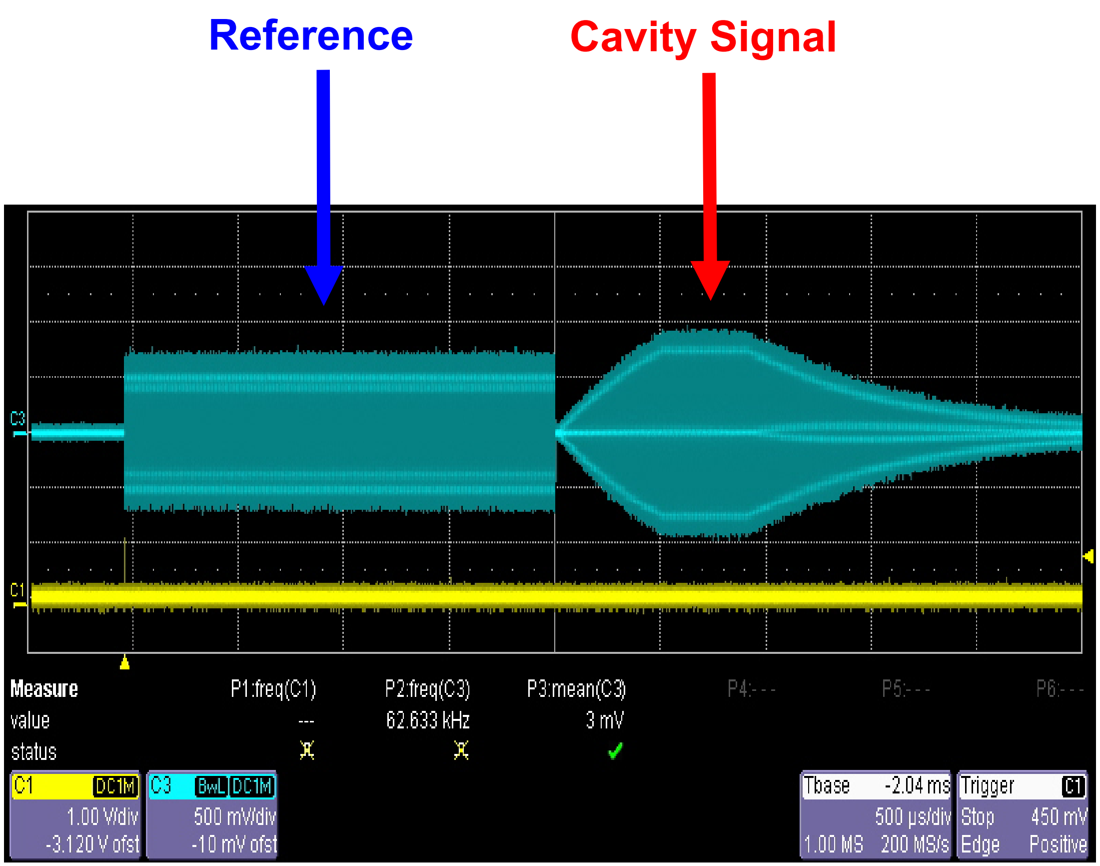


Reference Injection under Test in FLASH

- Setup ACC1 DEV-System :

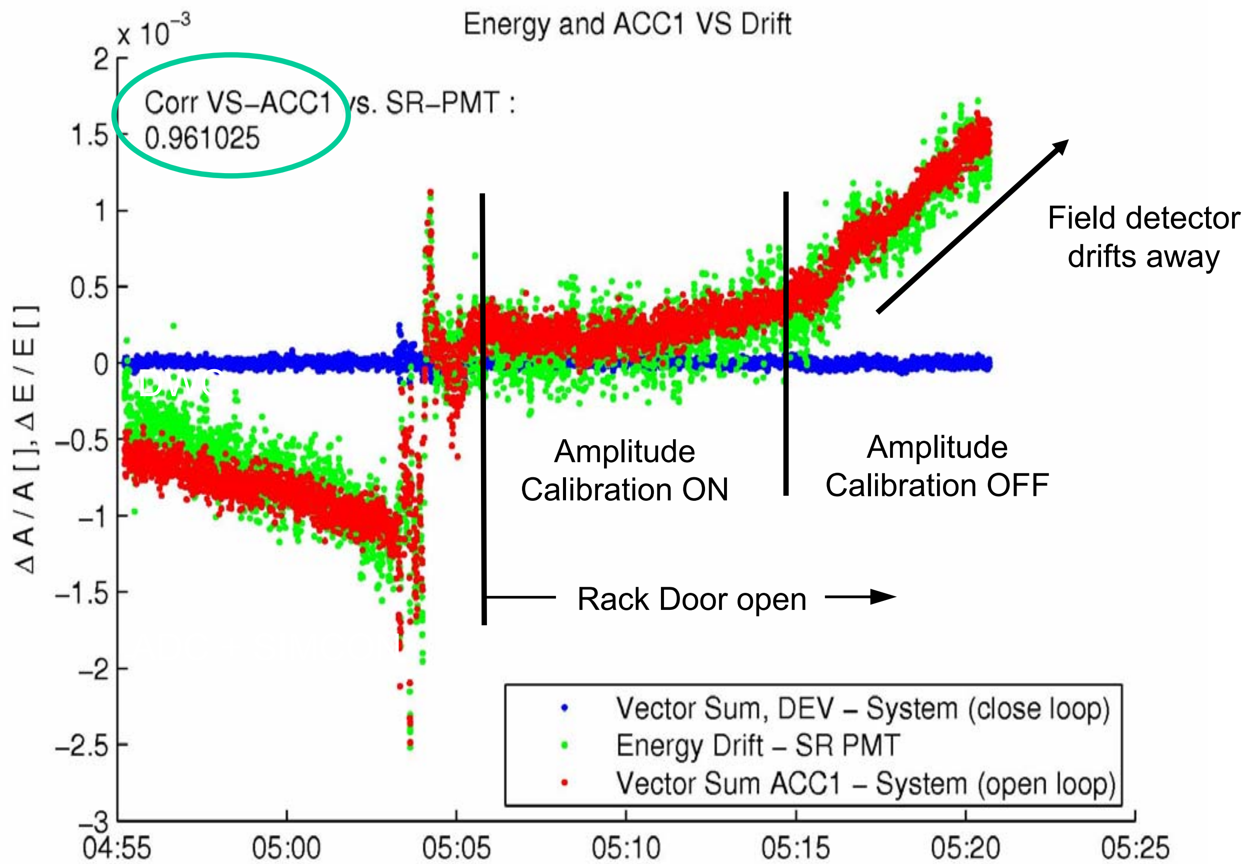


- ACC1 Calibration Signal / Cavity Signal :



Reference Injection under Test in FLASH

- Reference Injection for ACC1 in FLASH :



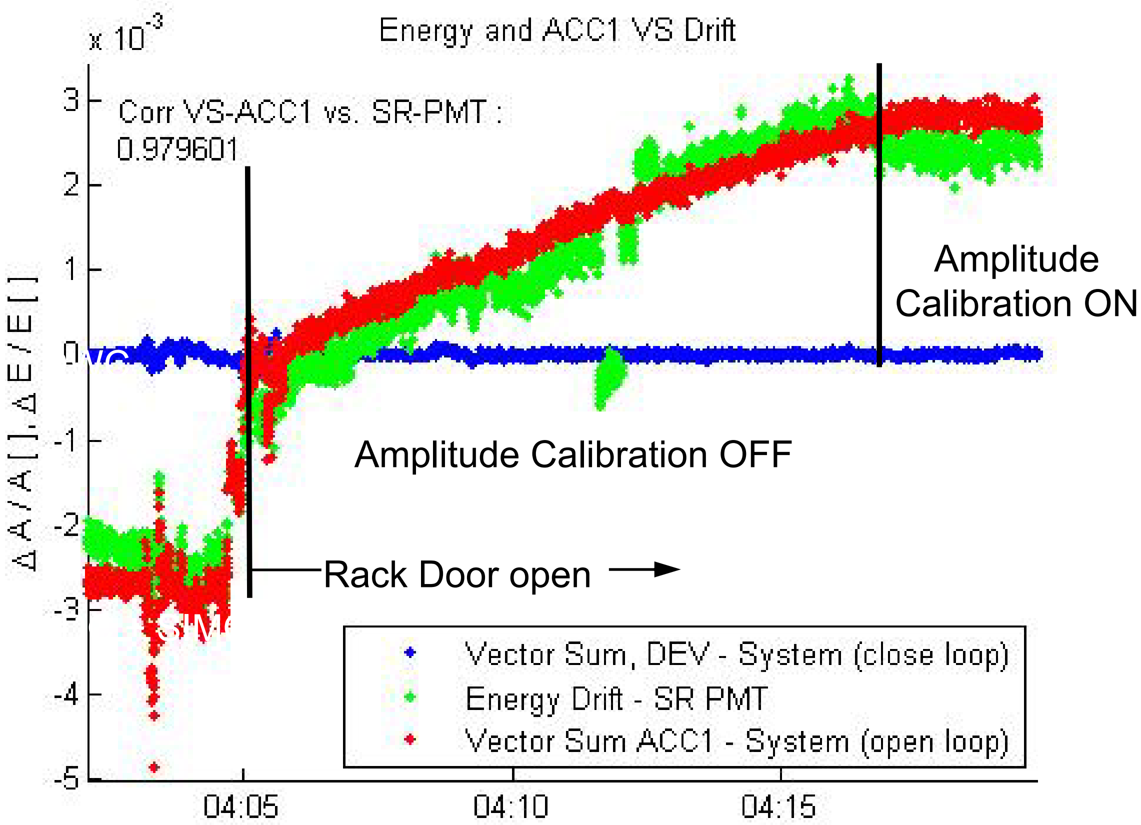
- Results :

- VS-ACC1 and SR-PMT amplitude drifts are correlated by 96%
- **Amplitude drifts dominate!**
- Phase drifts have minor effect!
- Injected amplitude calibration works

- Actual Limitations :

- Uncalibrated components, like attenuators, inner rack cables
- Unstabilized reference detection

- Reference Injection for ACC1 in FLASH :



- Results :

- VS-ACC1 and SR-PMT amplitude drifts are correlated by 96%
- **Amlitude drifts dominate!**
- Phase drifts have minor effect!
- Injected amplitude calibration works

- Actual Limitations :

- Uncalibrated components, like attenuators, inner rack cables
- Unstabilized reference detection

Summary

- SASE instabilities and the beam energy drift is mainly caused by ACC1 field amplitude drifts.
- Field detector drifts are caused by receivers temperature and humidity changes.
- The injected calibration eliminated field detector drifts on a scale of 2E-4 (pp) and 20fs (pp).
- The injected calibration is expected to be robust against cable vibrations.
- The injected calibration calibrates every pulse automatically and involves no feedback.

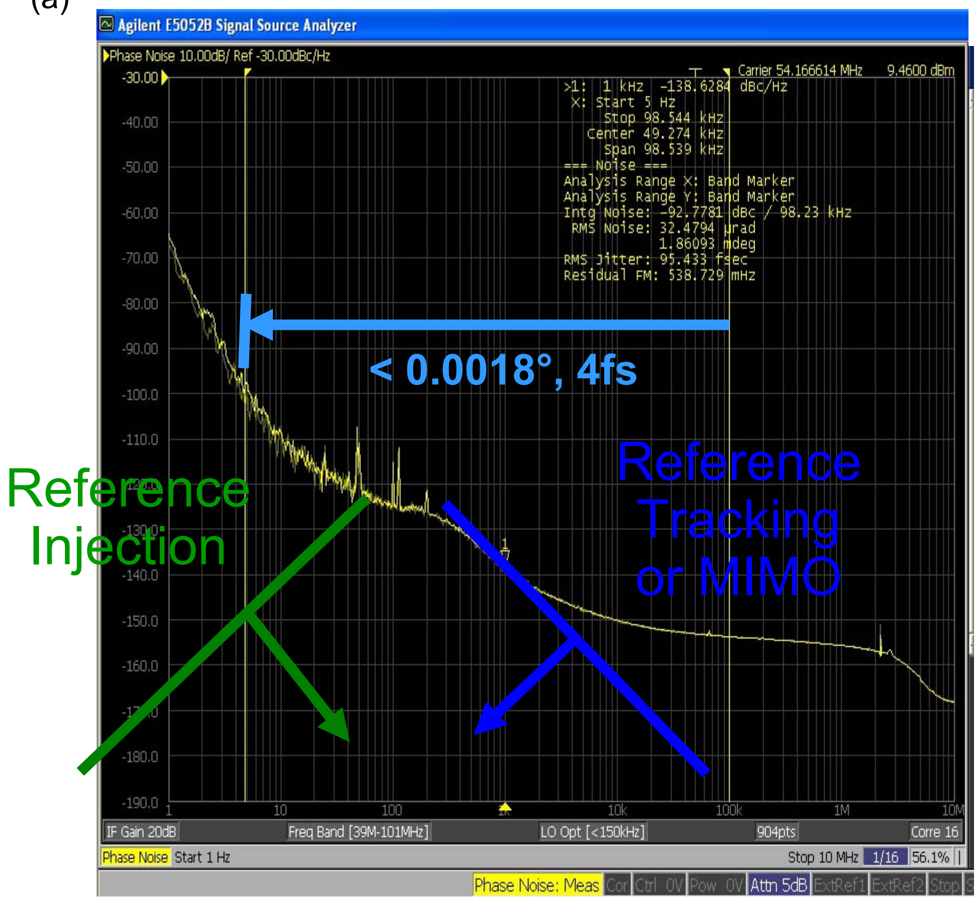
Outlook

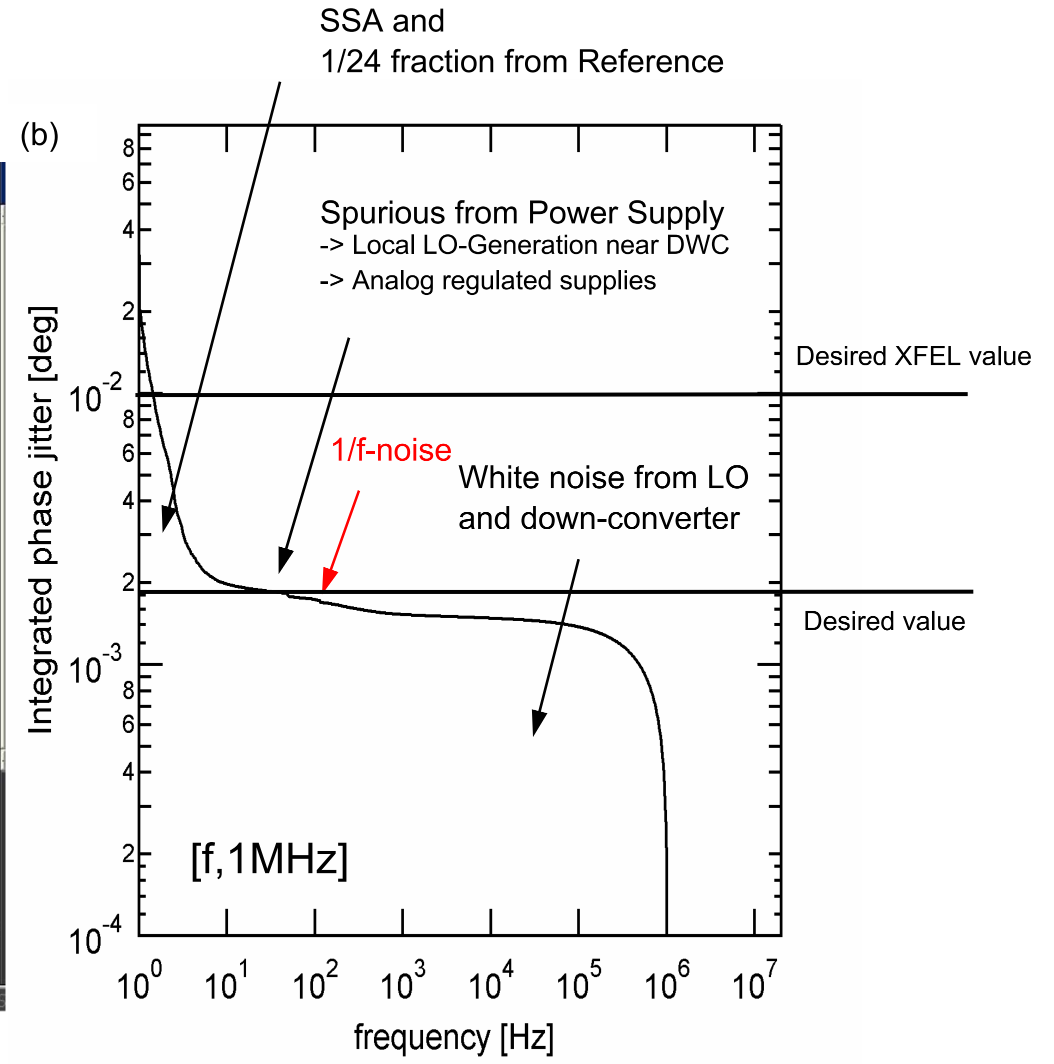
- Analog front-end receivers achieved 2m° [10Hz, 1MHz] phase stability.
- A microwave designed injection module will be tested at 3.9GHz FLASH (06/2010).
- The method has the potential to eliminate drifts from the complete LLRF pickup chain.

Special thanks to

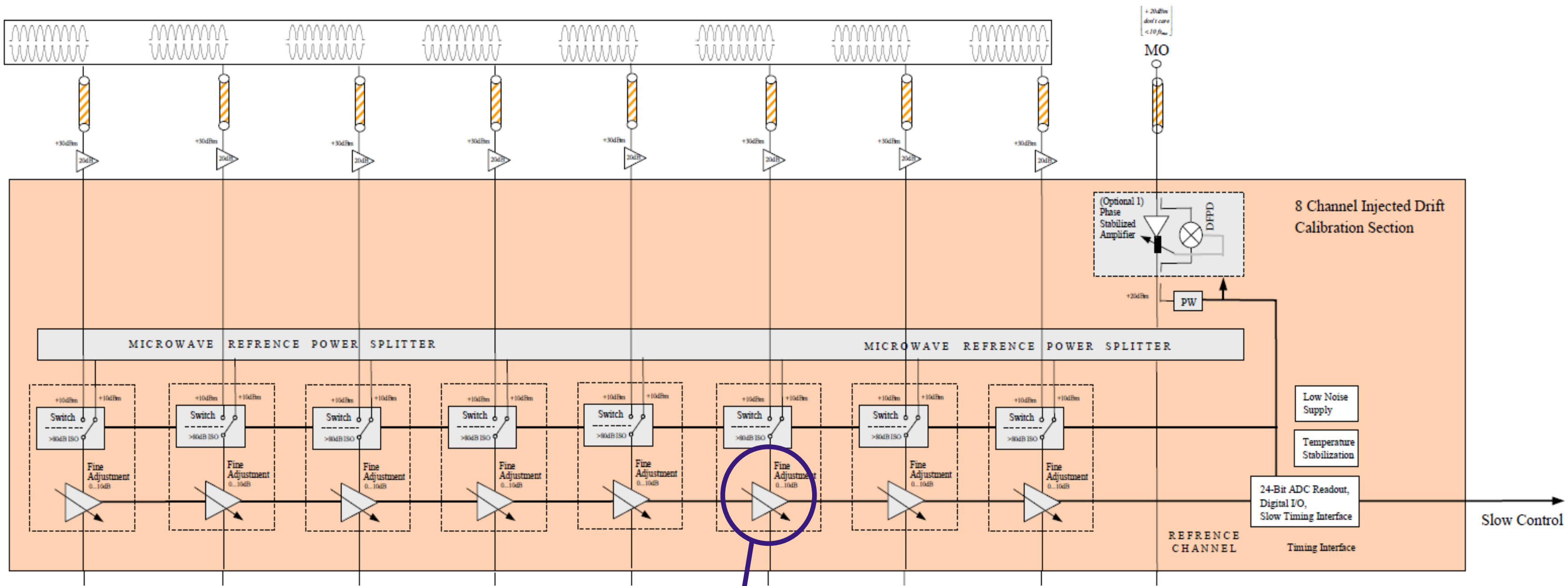
G.Möller

- Single channel IF receiver performance at FLASH (11/09) :

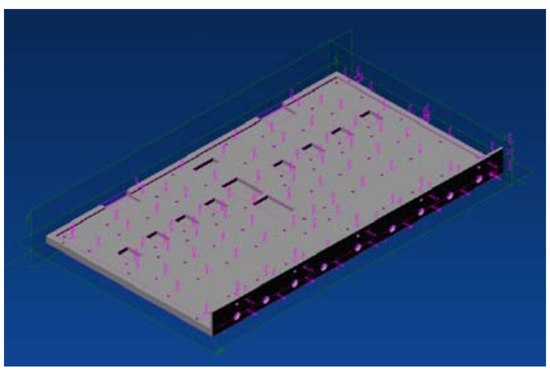




Phase I : XFEL Automated Field Detection Drift Calibration F.Ludwig / DESY/ 24.06.09



Packaging for passive thermal stabilization :

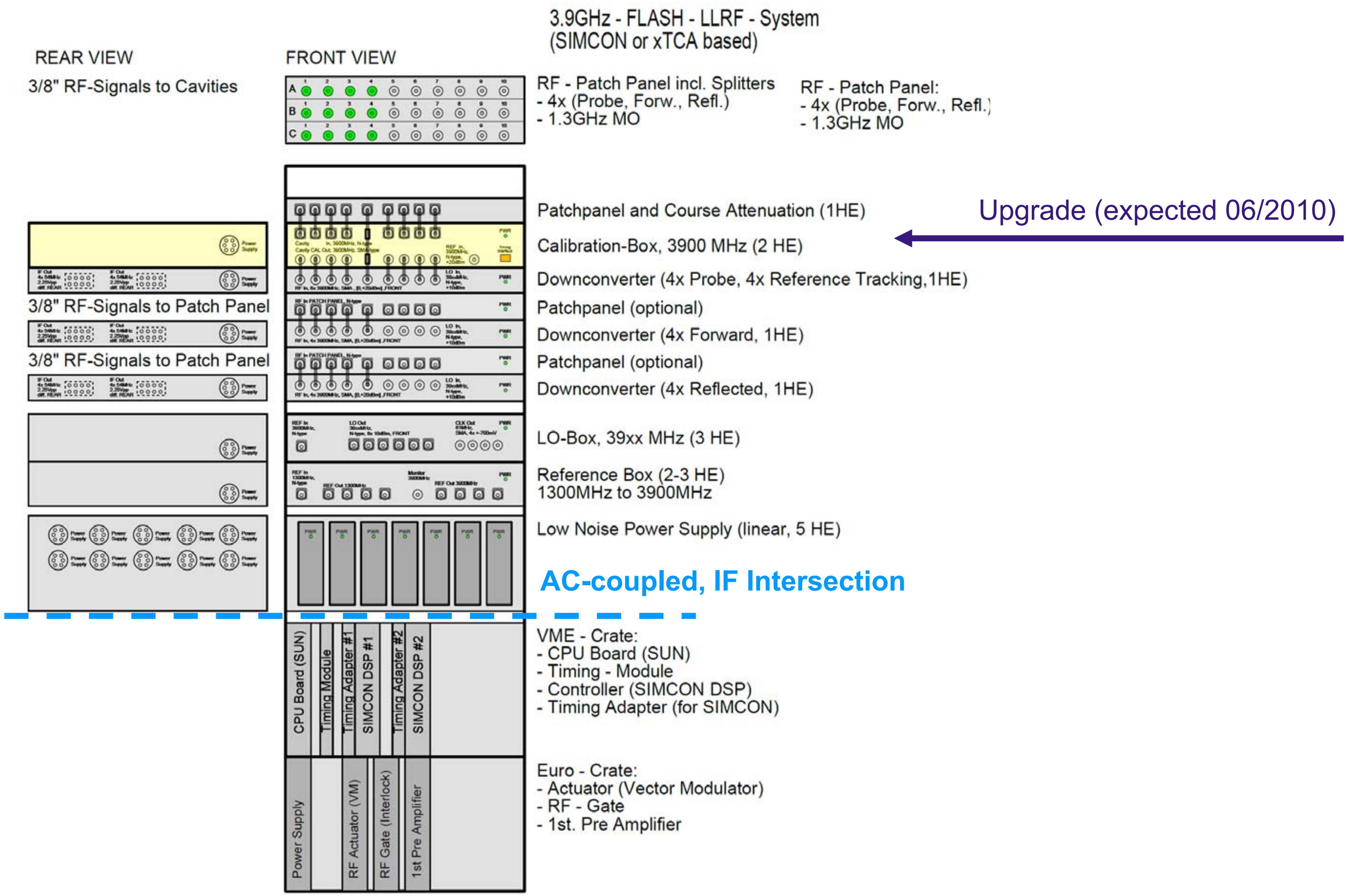


Phase dependent,
inside calibration loop

CAL-Module (2HE,19") – Injected Calibration:

-8 signal calibration channels + 1 calibration line for channel linearization
-RF-Inputs 1300MHz, 20dBm, N-type connectors
-RF-Outputs 1300MHz, 20dBm, SMA-type connectors
-Switching state 3 cell high isolation switches
-Adjustable 0…10dB attenuators after calibration stage
-Amplitude low drift rf-power level detection <1E-5 long-term stability
-Amplitude rf-power detection temp. controlled <0.1deg.
-24-Bit ADC/ 100kHz rf-power level detection
-Integrated reference distribution operable at 3.9GHz and 1.3GHz
-Channel Isolation >80dB, optionally top shielded by housing
-Interface I^2C for data readout
Option #1: Direct Sampling for low drift reference readout
Option #2: Calibrationa line +1 DWC channel

Reference Injection for ACC39 at FLASH



Thanks for your attention !