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Libera LLRF

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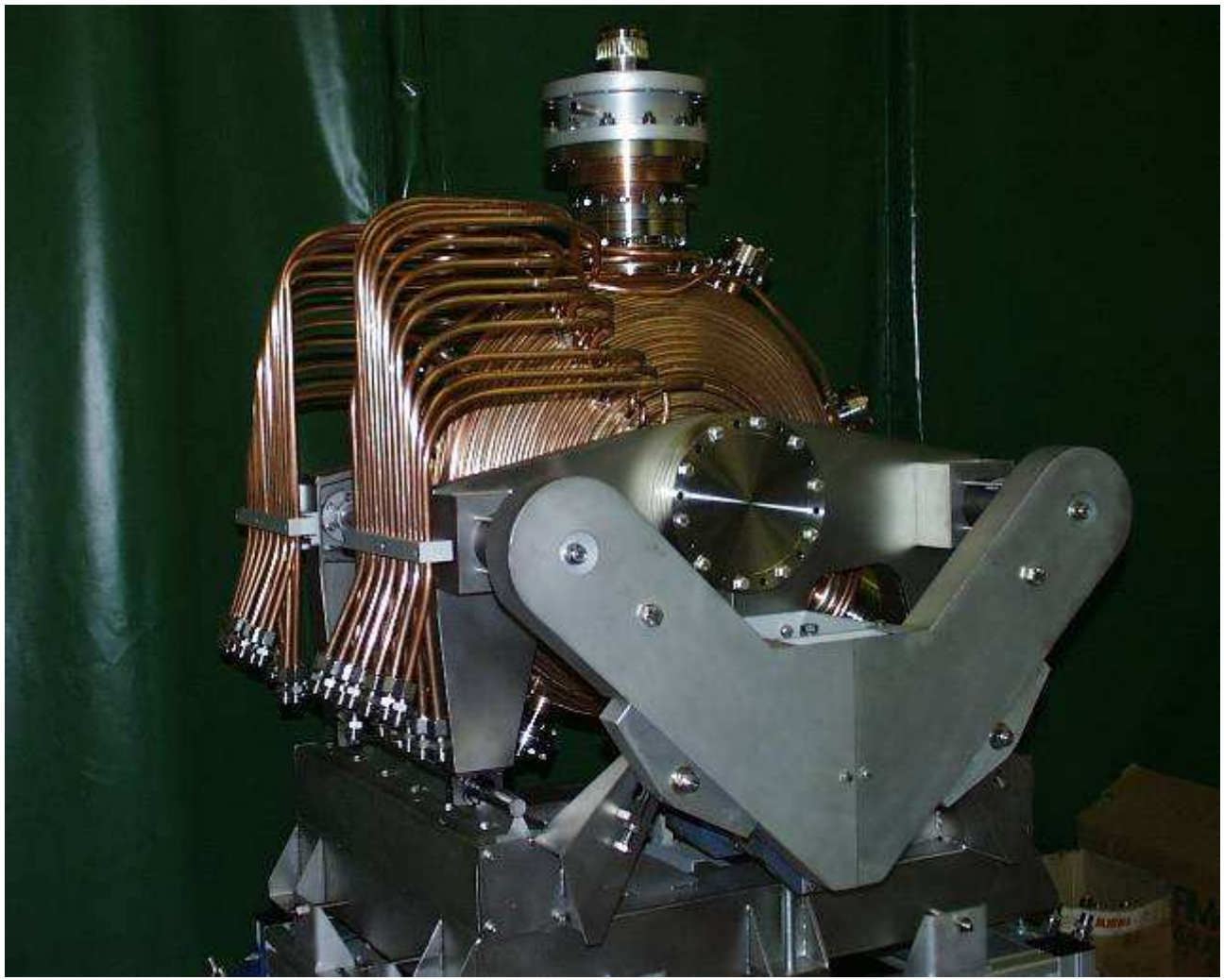
Libera WORKSHOP 2008

13. October 2008

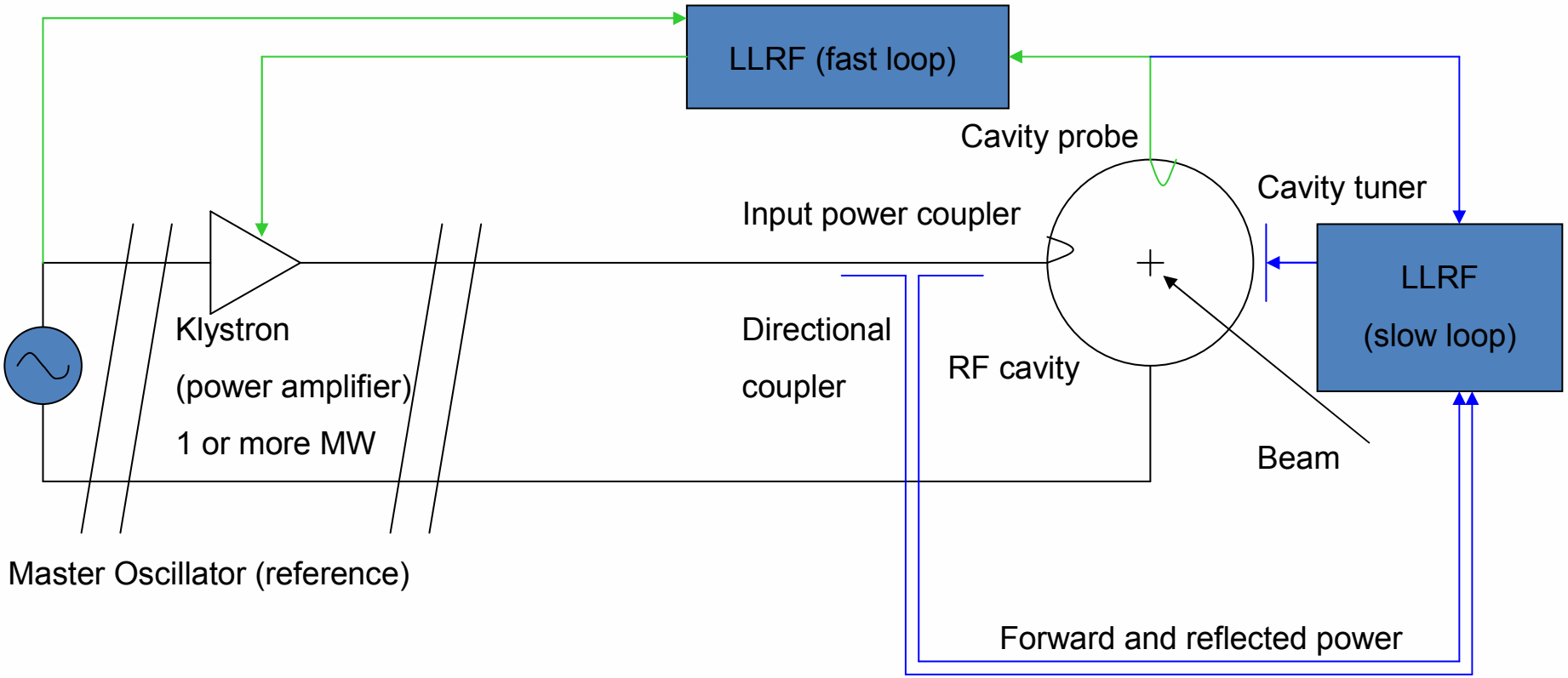
Libera LLRF system

- **Digital RF stabilization system:**
  all-in-one,
  customizable,
  ready to integrate in the control system

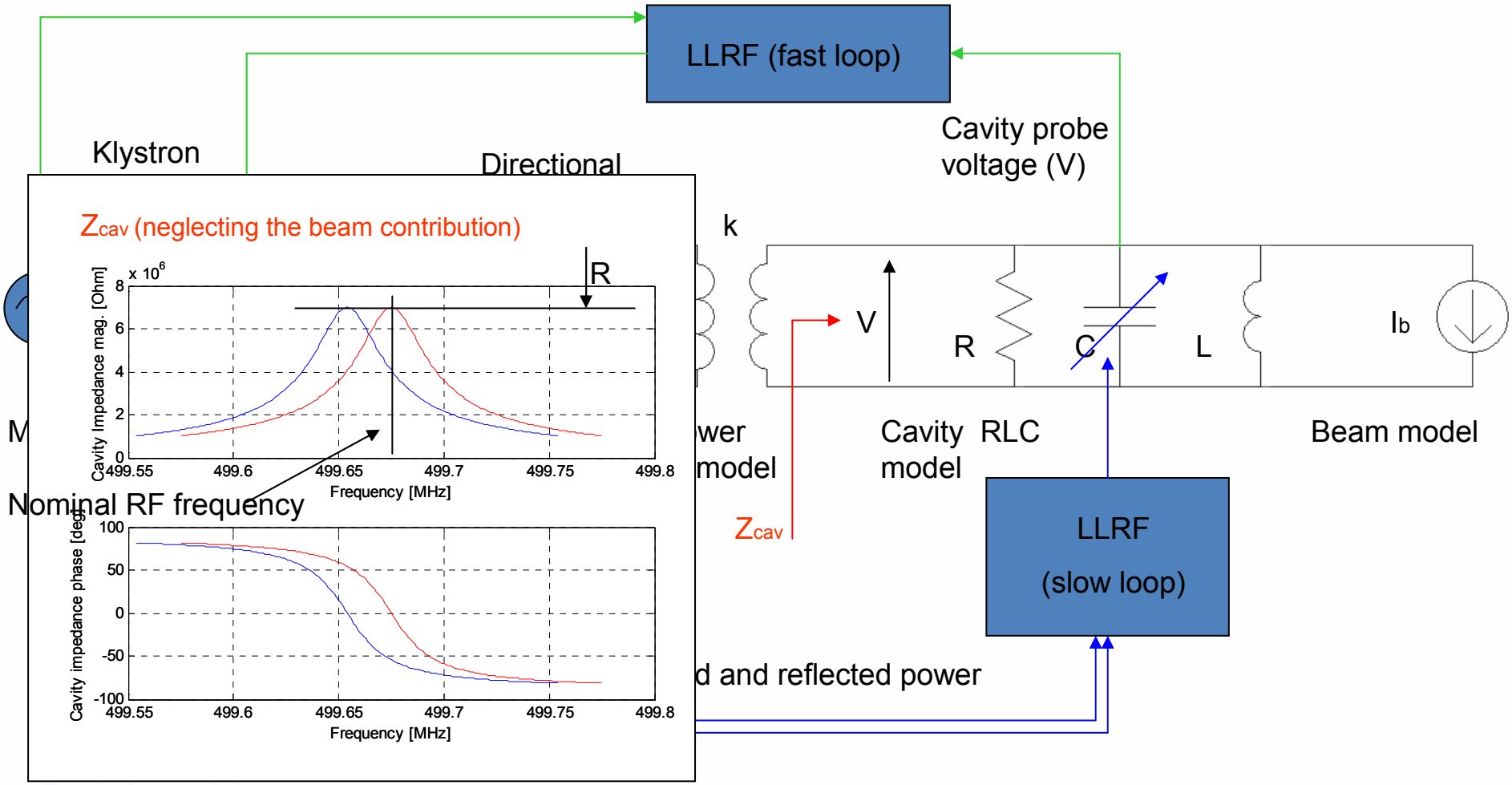
RF cavity (“Elettra” 500 MHz, Q=42000)



RF system & LLRF

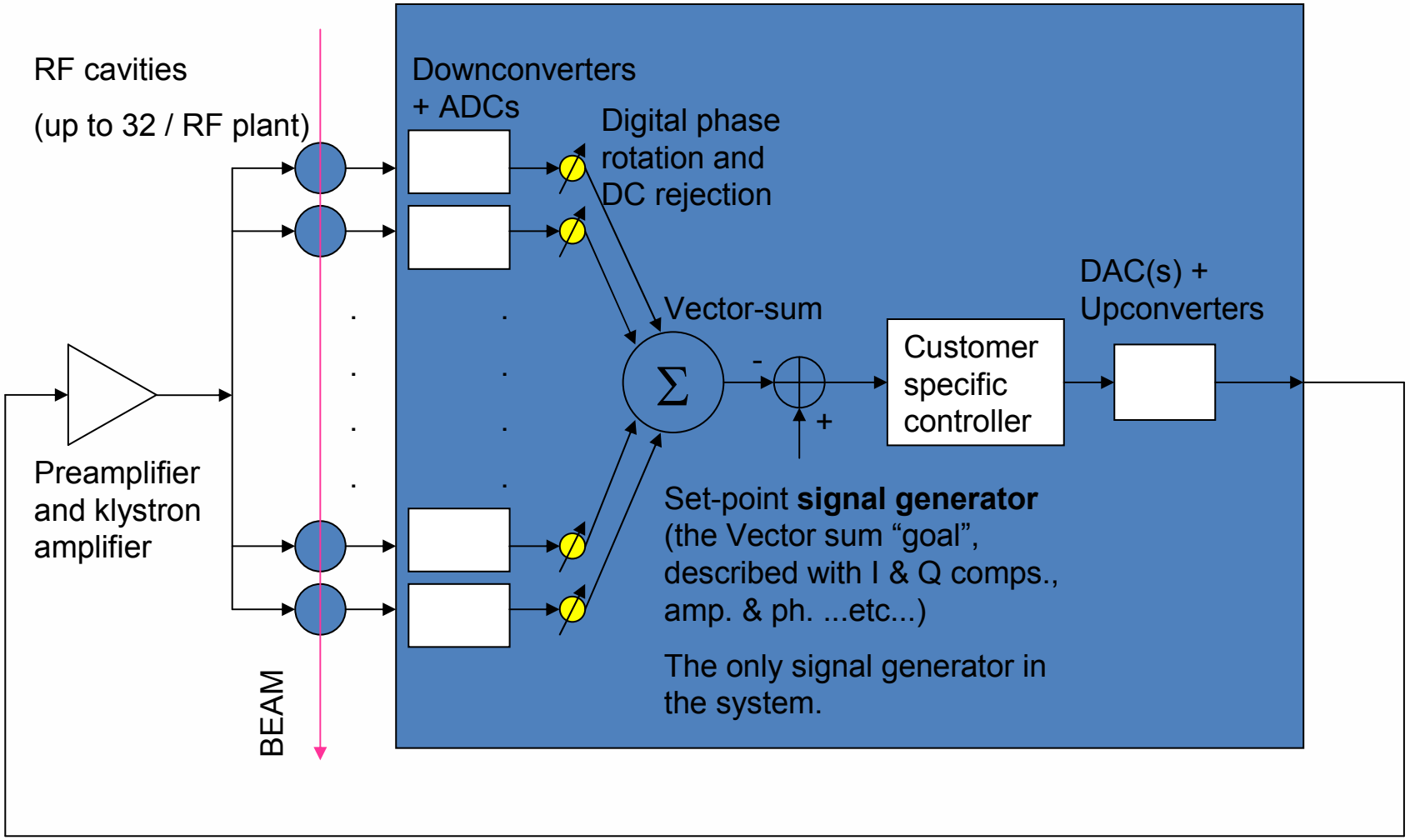


LLRF and cavity-beam model



LLRF system

LLRF System (implementing the cavity field stabilization)



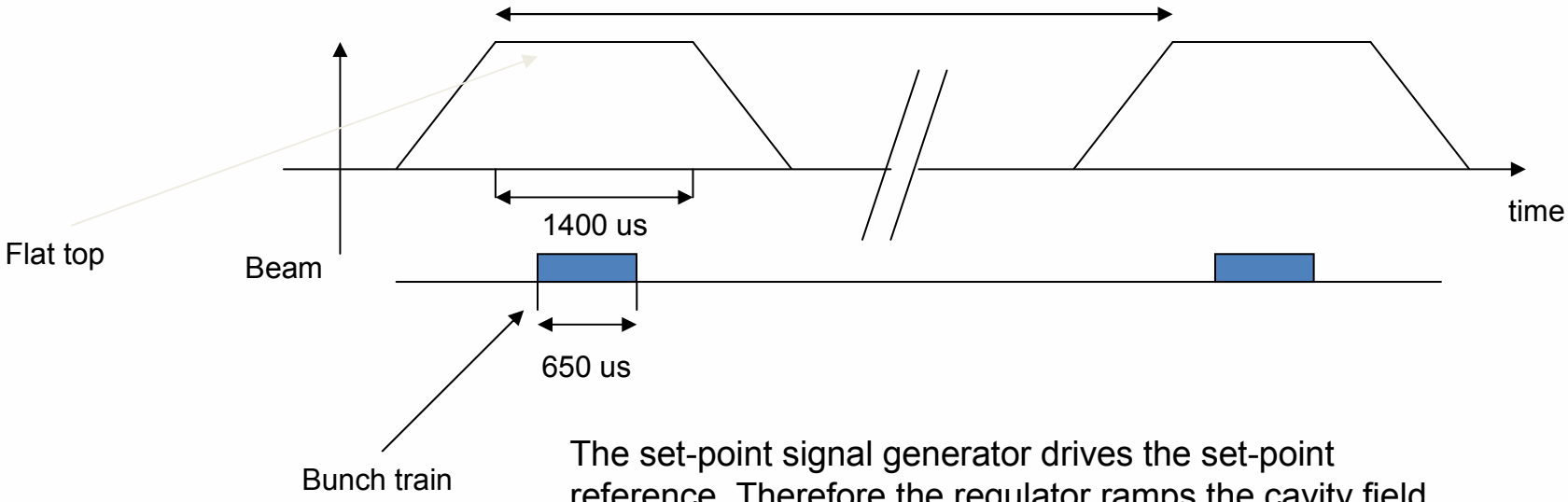
RF system characteristics

1) SuperConducting vs. NormalConducting RF systems:

- NC: EMMA: RF freq. 1.3 GHz, BW=56 kHz, Q=23000
- SC: XFEL: RF freq. 1.3 GHz, BW=100 Hz, Q=13E6 (sophisticated tuning system (piezo))

2) Pulsed vs. CW:

- CW: RF field on all the time (storage rings)
- Pulsed systems: RF field active during a limited period of time (few ms) repetition rates from 10 Hz to 100 Hz



The set-point signal generator drives the set-point reference. Therefore the regulator ramps the cavity field.

Libera | LLRF

Digital RF stabilization system

ALL-IN-ONE / Integrated

The all-in-one unit replaces a field of different instruments and crates:

- Built-in RF system diagnostics: automatic phase and gain correction, cavity field control loop stability analysis, cavity decay analysis monitoring
- Cavity tuning included
- Cavity field stabilization: jitter cancellation, vector sum alignment, calibration system, computation of the cavity field vector sum, cavity field control by means of a programmable PI controller, feed-forward system
- Built-in interlock system
- Self calibration
- Chassis health monitoring
- Built-in local oscillator generation

SUITABLE FOR THE LATEST GENERATION LIGHT SOURCES and HADRON ACCELERATORS

- Phase and amplitude stability meets 4th generation light sources' requirements
- Compatible with normal-conducting and super-conducting RF systems
- Supports pulsed and continuous wave operation modes
- Low latency

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Instrumentation Technologies

Hardware Interfaces

Intel dual core COM Express with extensive communication interfaces:
The latest FPGAs and a powerful personal computer based on the PCIe interface offer good resources for the implementation of low-latency control algorithms, real-time data processing and dedicated RF system diagnostics tools.

Vector modulator module:
Receives the partial vector sum signals from four satellite ADC modules through low-latency low-voltage differential signaling (LVDS) lines. The global vector sum is then processed by means of FPGA algorithms. The output of the control algorithms is then up-converted to the RF frequency and used as the transmitter drive signal.

Optional fast communication modules

Timing module:
Generates a low jitter local oscillator (LO) signal and a suitable sampling clock for the down-conversion and acquisition processes. The designed acquisition structure enables a high level of amplitude and phase cavity field stabilization.

RF acquisition modules:
The system is configured to have four satellite modules, each of which can process up to 9 RF inputs. One channel on each board is used as RF reference signal for measurement and jitter cancellation purposes. Each RF acquisition module includes a built-in calibration system, temperature stabilization, jitter cancellation, LO distribution, partial vector sum computation and vector sum phase alignment functions.

LLRF signal levels

ADC9:

-RF inputs 1-9: 20 dBm

-Cal. input : 20 dBm

-LO input : 0 dBm

TCM:

-Ref. Input : 0 dBm

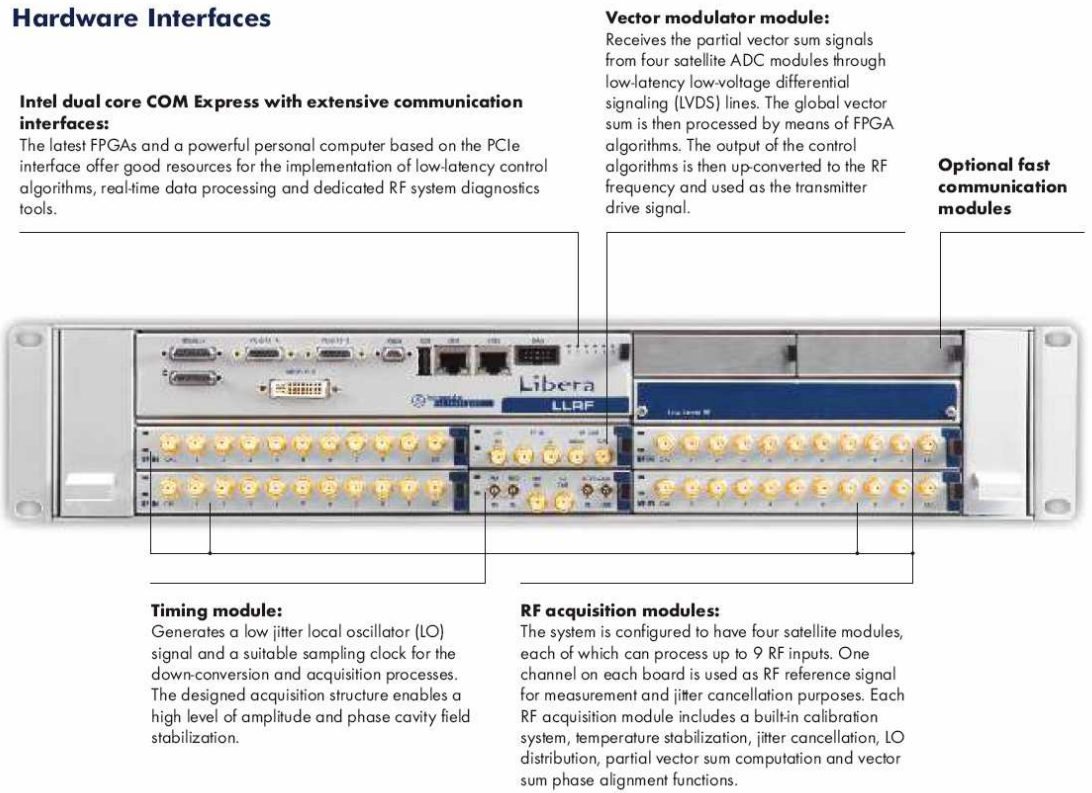
-LO output : 18 dBm

VM:

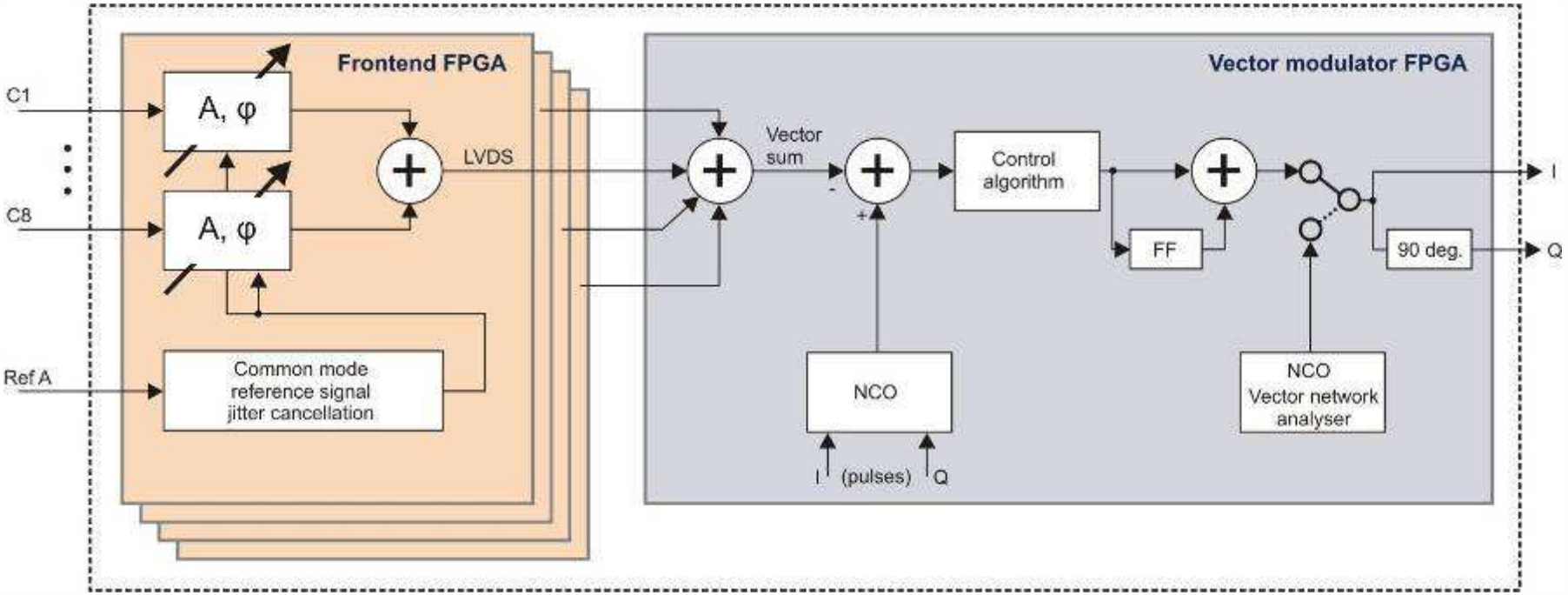
-LO input : 0 dBm

-RF in : 20 dBm

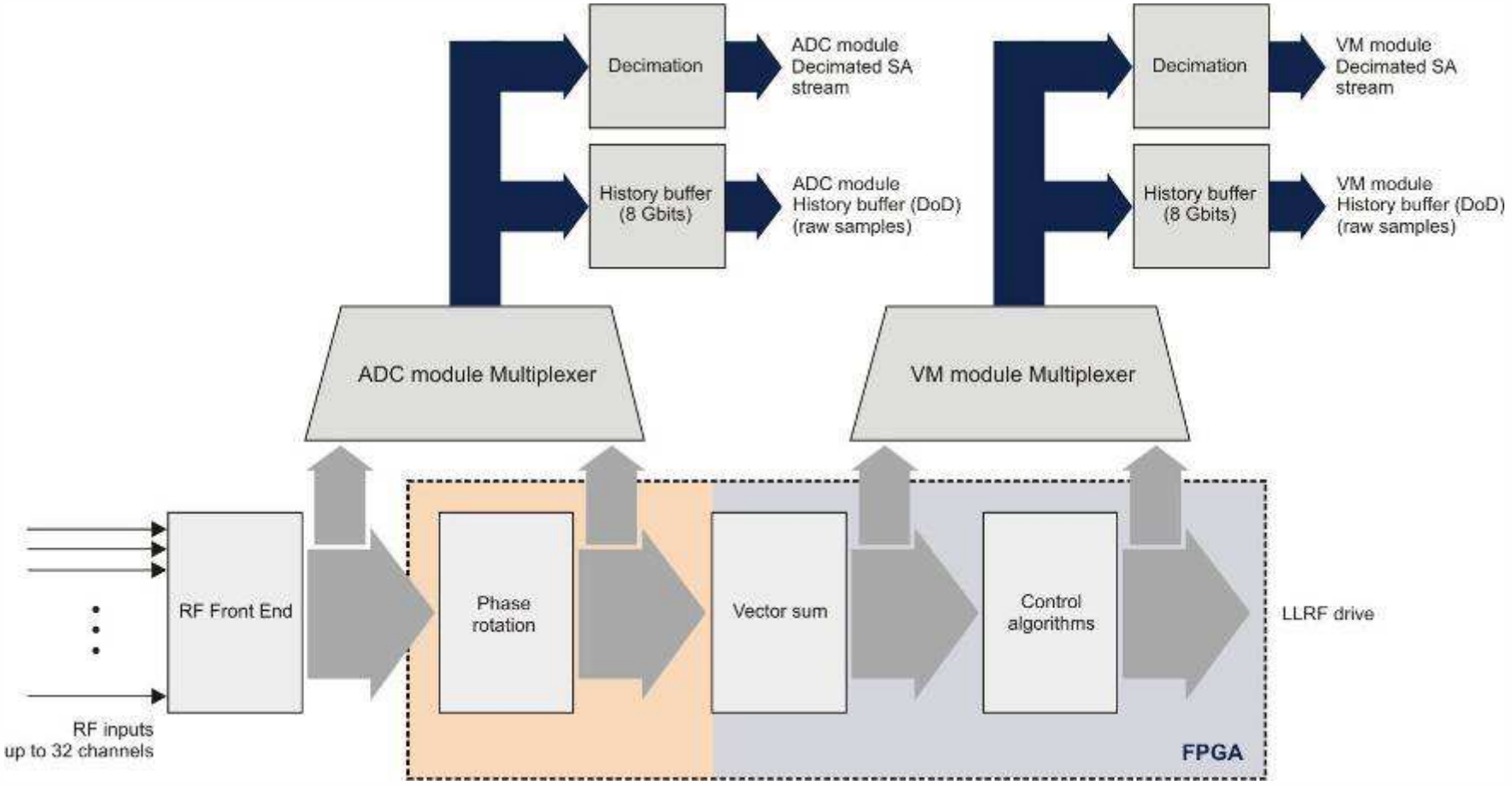
-RF out : 12 dBm



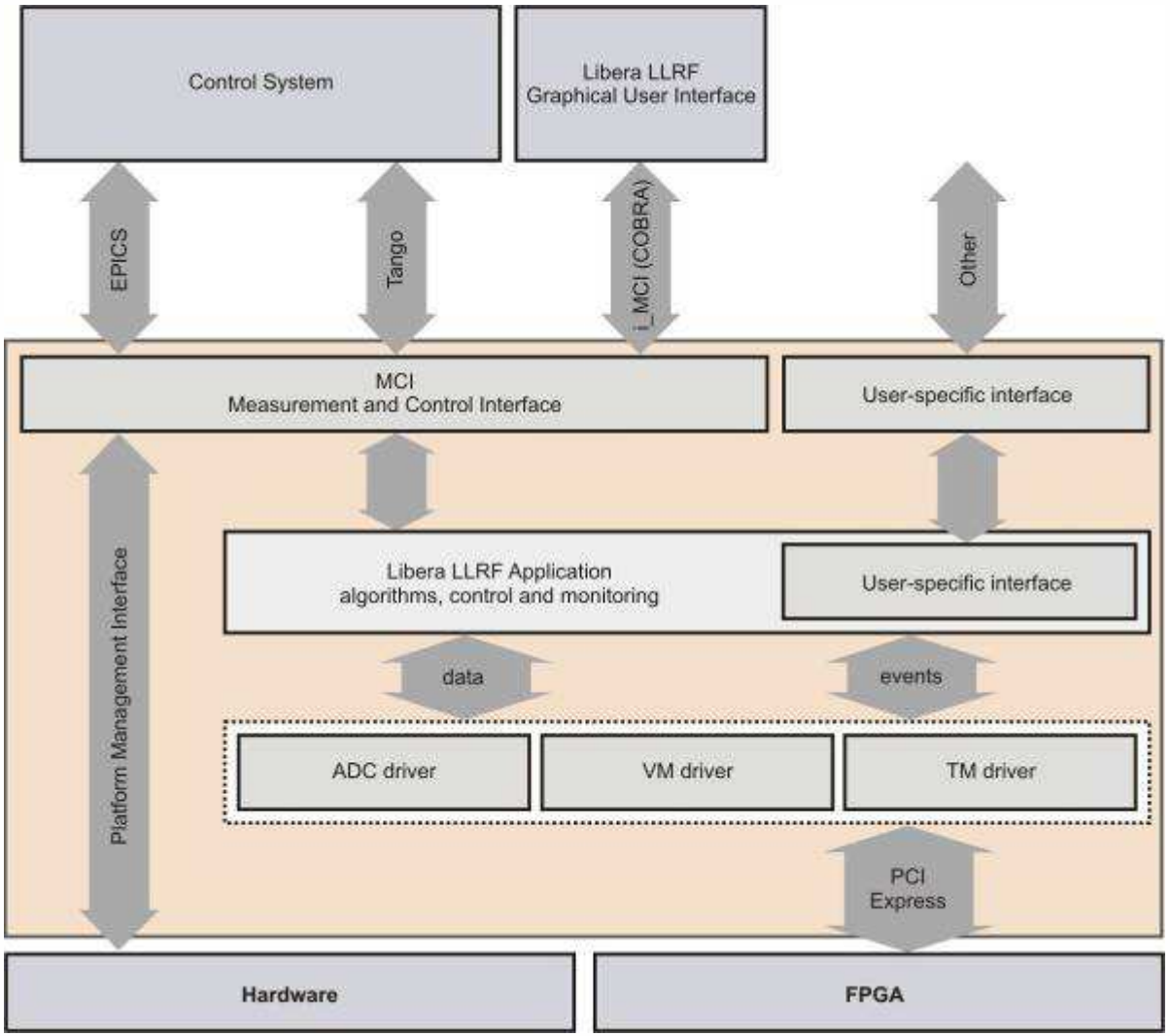
Distributed processing



Data paths


Decimation
ADC module
Decimated SA
stream
History buffer
(8 Gbits)
ADC module
History buffer (DoD)
(raw samples)
Decimation
VM module
Decimated SA
stream
History buffer
(8 Gbits)
VM module
History buffer (DoD)
(raw samples)
ADC module Multiplexer
VM module Multiplexer
RF Front End
Phase
rotation
Vector sum
Control
algorithms
LLRF drive
RF inputs
up to 32 channels
FPGA

SW interfaces



GUI

Flat top analysis

The cavity voltage amplitude and phase stability can be easily measured from the acquired samples. A long history of raw samples is available from the buffer. The effectiveness of the control algorithms in suppressing disturbances of the cavity field, can be measured using this tool.

Decimated signals

All the signals of the Libera LLRF system are also available in a decimated form for easy processing and display on control system screens. The cavity response to RF pulses is already available in the form of amplitude and phase signals.

RF system diagnostics

During operation, the cavity decay analysis and directional coupler signals are used to monitor and control the cavity tuning.

Nyquist stability analysis

A powerful RF diagnostics system completely characterizes the RF system by means of built-in network vector analysis. Libera LLRF automatically uses diagnostic measurements to compute the optimal phase rotation for enabling a stable LLRF loop. The user is also provided with phase and gain stability margins. The open loop transfer function is displayed on a Nyquist diagram. The application suggests the optimum working parameters.

System monitoring

The Libera LLRF system has an advanced health monitoring system that takes care of fans, voltages and temperature.

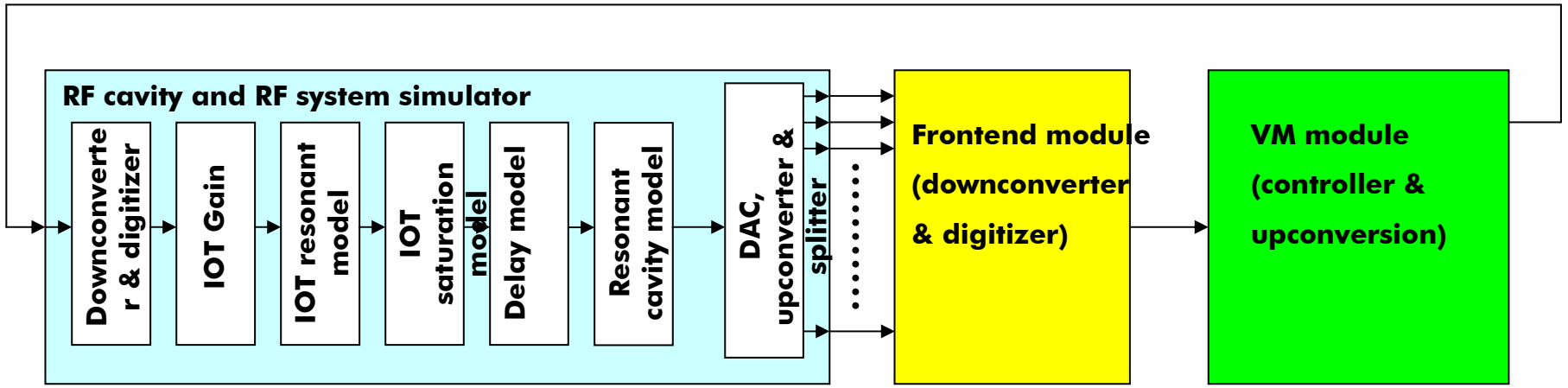
Configurable LLRF controller application

Parameter	Value
Number of input channels	36 (9 per module)
ADC resolution	16 bits
Max. ADC sampling clock frequency	130 MHz

Cavity simulator

Designed to model the CPI IOT power amplifier non linear effects, limited bandwidth and the EMMA NC cavity.

- Based on upconversion and downconersion chains + BBFP
- Nominal RF frequency 1.3 GHz
- Nominal BW= 56 kHz (Q=23000)
- IF frequency 100 MHz
- Sampling frequency for IF 350 MHz
- Conversion LO frequency: 1400 MHz
- other features: variable gain, phase, resonant frequency and group delay



Libera LLRF performance

Input RF chain crosstalk (far end): - 70 dB

Crosstalk ratio at IF level: - 60 dB

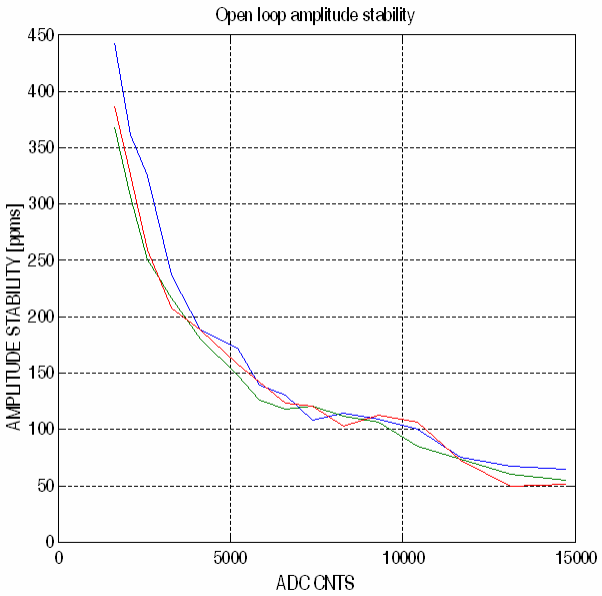
Open loop stability:

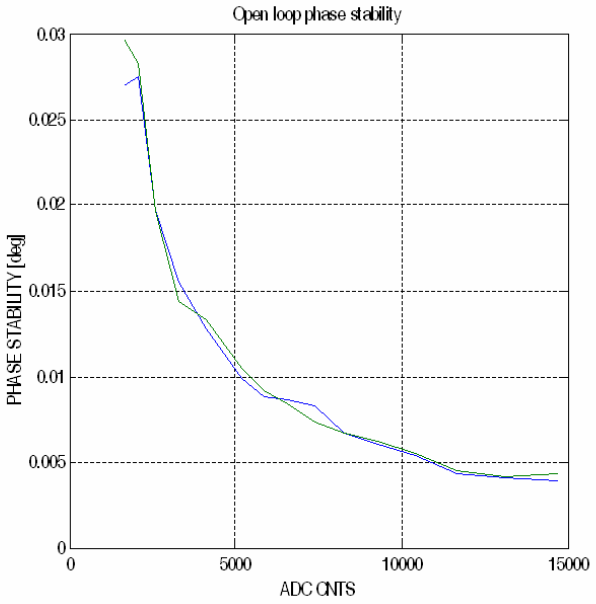
Amplitude: 0.007 %

Phase: 0.005 deg

Estimated latency: 200 ns

	-80.9	-78.7	-80.1	-81.2	-81.7	-83.2	-81.9	-80.2
-73.3		-73.3	-82.1	-80.9	-81.7	-82.5	-82.7	-79.7
-79.9	-69.2		-83.7	-78.4	-80.8	-82.4	-82.5	-80.1
-81.7	-81.4	-72.7		-73.4	-79.1	-80.8	-82	-80.6
-81.1	-82.8	-80.8	-73.4		-76.7	-79.2	-79.7	-78.4
-82.4	-83.5	-82.4	-80.6	-76.4		-79.8	-77.2	-77.5
-82.3	-84.5	-82.9	-82.2	-82.8	-70.5		-83.8	-76.9
-81.1	-83.8	-83.8	-82	-82.5	-79	-71.1		-88.5
-80.3	-81.8	-82.6	-80.7	-79.5	-83.4	-80.2	-70.7	





Thank you!

XFEL LLRF example