LLRF for TTF II

Stefan Simrock

(for the LLRF team)

DESY

- General
- Configuration of RF Systems
- Amplitude and Phase Stability
- Operational Requirements
- Design of LLRF for TTF II
- Outlook

General LLRF Requirements

- Set and maintain accelerating fields during TTF II operation as
  - UV FEL user facility
  - Tesla Test Facility
- Cavities to be controlled:
  - RF Gun (nc)
  - 3rd harmonic cavity (3.9 GHz)
  - Vector-sum of cryomodule 1
  - Vector-sum of cryomodules 2+3
  - Vector-sum of cryomodules 4,5,6,(7)
  - S-Band cavity (nc) at 2.856 GHz
  - Provide stable phase reference for Laser, and diagnostics

Amplitude and Phase Stability

- Typically requirements are
  - $\sigma_A/A < 10^{-3}$ amplitude
  - $\sigma_\phi < 0.3$ deg. for phase (fast fluctuations)
    - Must distinguish correlated and uncorrelated errors, intra-pulse, inter-pulse, and long-term (thermal > minutes). Long term stability of better than 1 deg. is difficult to achieve.
- Other requirements
  - ACC1: cav. 1-4 at 12.5 MV/m, cav. 5-8 at 20 MV/m phase of accelerating field -10.8 deg.
  - ACC39 at 14 MV/m at 183 deg.
  - S-Band cavity at 2856 MHz phase stability < 1 deg.
  - RF Gun operation without field probe. Rep. rate, pulse length and power must be variable.

Operational Requirements

- Field Calibration
- Beam phase measurement
- Beam loading compensation
- Finite State Machine
- Exception handling
- Cavity frequency tuning
  - motor tuner
  - piezo tuner
- Adaptive feedforward
- Waveguide tuner control

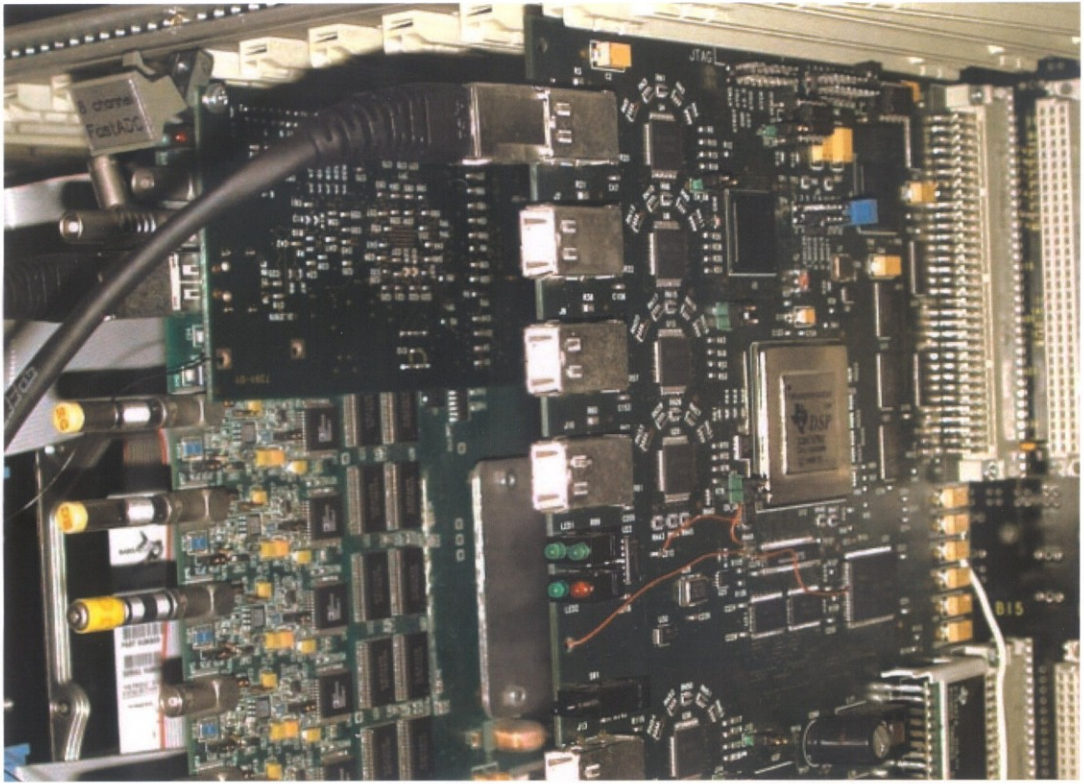
LLRF for TTF II

- Digital Feedback
  - C67 based DSP board
  - 8 channel ADC boards
  - 8 channel DAC board
  - Gigalink interface between boards
- Downconverter based on AD 8343
- Master Oscillator and Frequency Distribution
  - New Frequencies 13.5 MHz and 2856 MHz

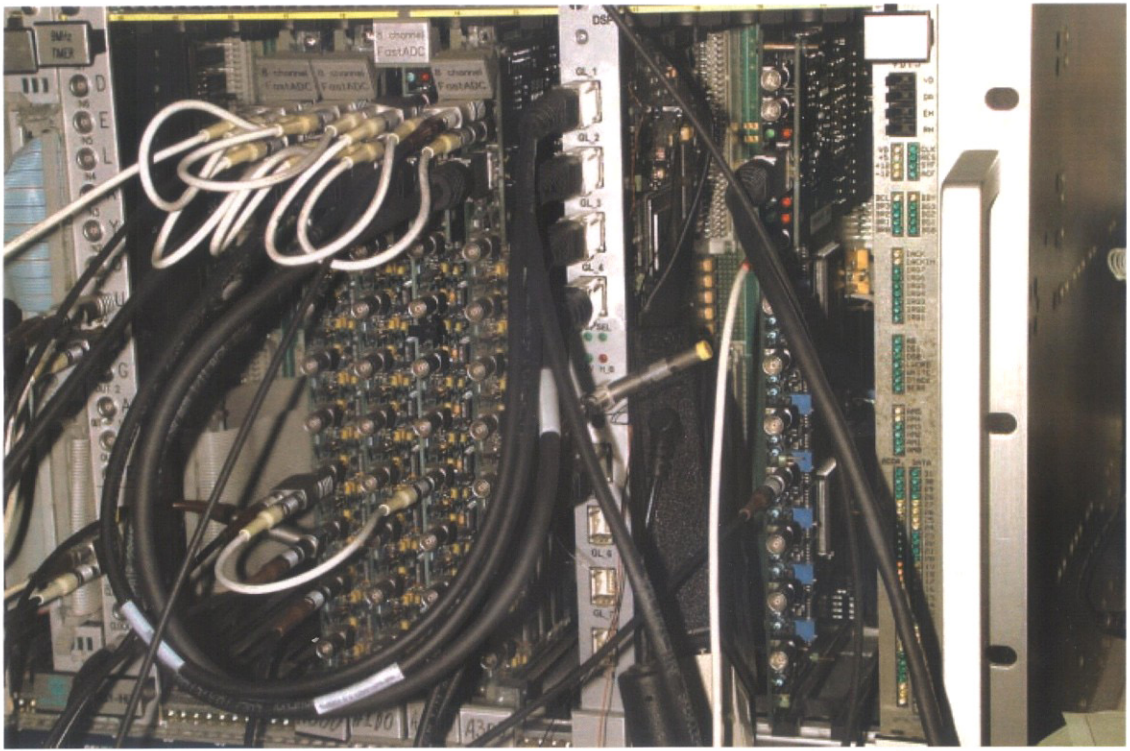
LLRF Subsystems/Components

- o RF phase reference
  - from main driveline
  - LO for downconverter
- o Timing System
- o Vector modulator
- o Downconverter
- o Digital Control (Fdbck + FF)
  - ADC, DSP, DAC
  - includes exception handling
- o Redundant simple feedforward
- o Redundant monitoring system
- o Transient detection
- o Interfaces to other subsystems
  - includes interlocks
- o Waveguide tuner and controls
- o Cavity resonance control
  - slow (motor) tuner
  - fast (piezo) tuner
- o CPU in VME crate
- o Network to local controls
- o Cabels and connectors
- o Power supply for electronics
- o Airconditioning in racks
- o Software
  - DSP (FPGA) code
  - server programs
  - client programs
  - LLRF Parameters
  - Finite State Machine

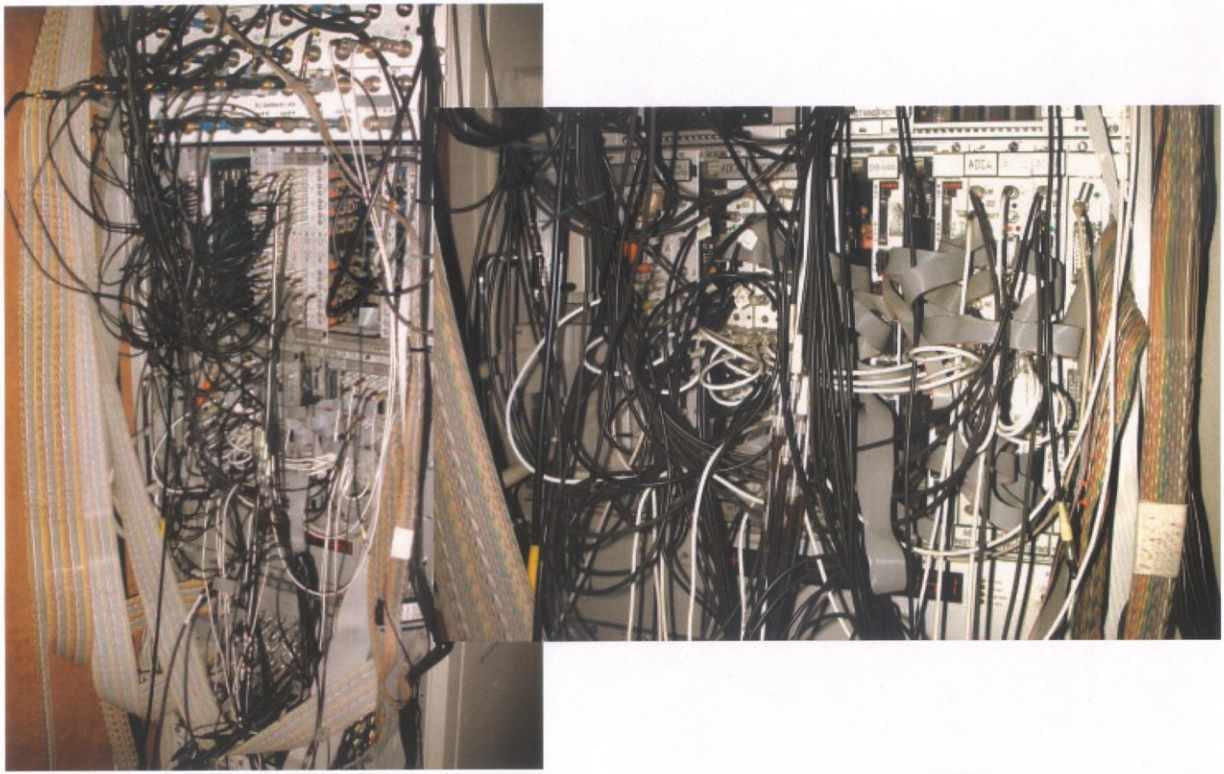
C67 DSP board



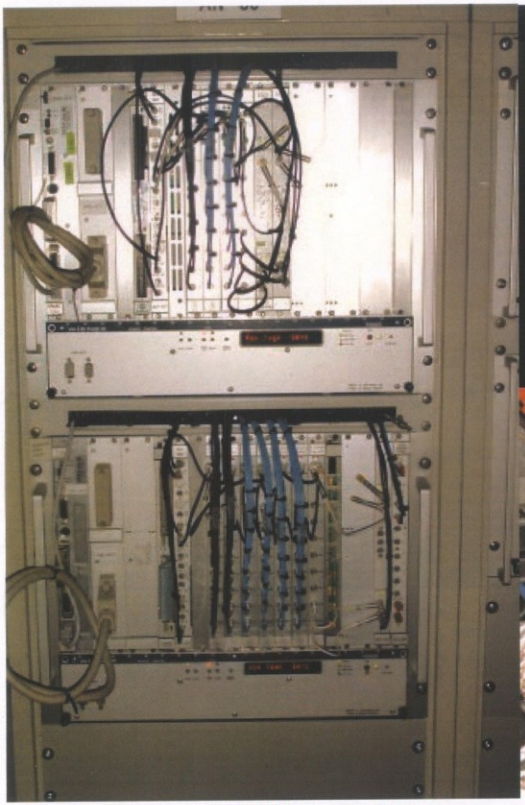
C67 DSP board

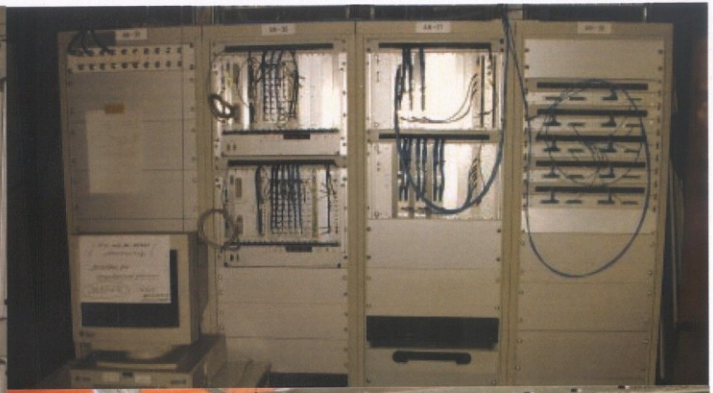


Rack Layout and Cabling for TTF I

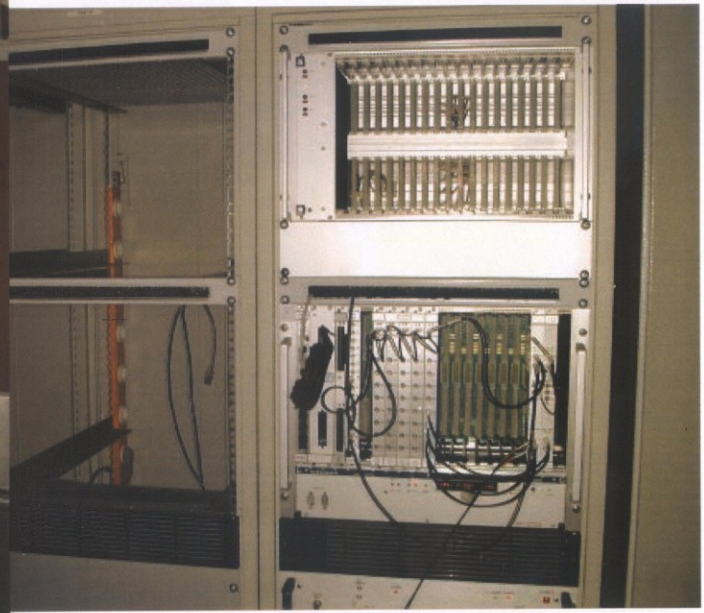


Installation Status of LLRF for ACC 2-6

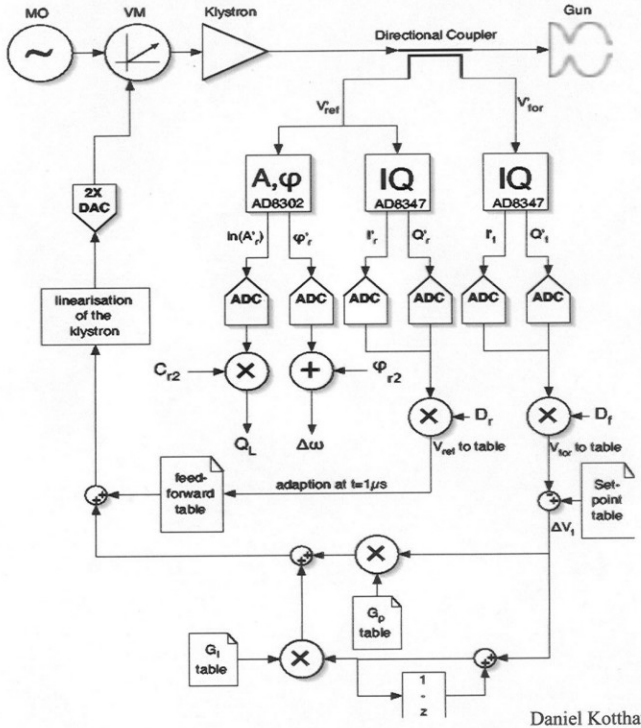




Installation Status of LLRF for M.O., RF Gun & ACC1



FB and FF Scheme

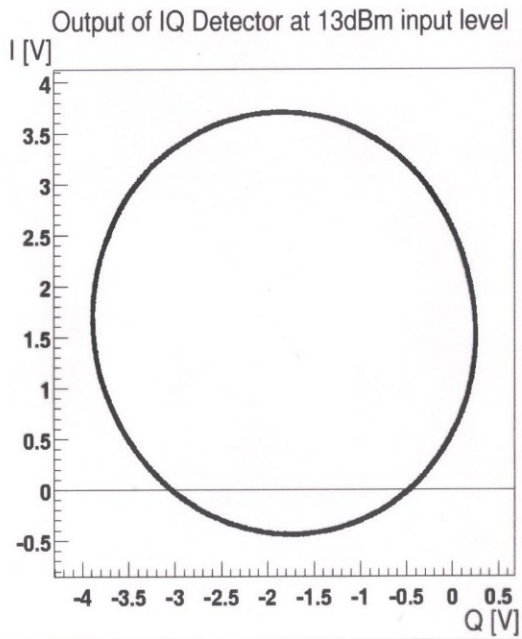


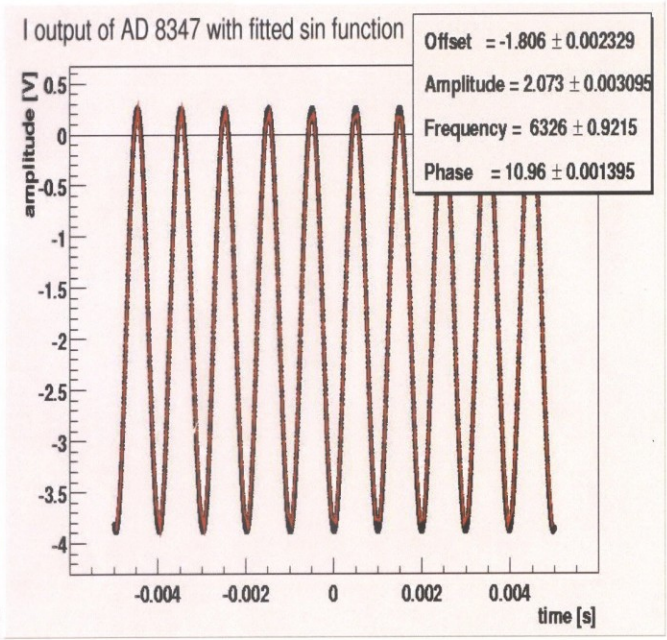
- No probe in the cavity
  - $V_{acc}=V_{for}+V_{ref}$
- Feedback on V_{for} (later with V_{acc} ?) with variable G_p and G_I
- Feedforward on V_{for}
- adaption of FF with V_{ref}

Detectors for Gun Control

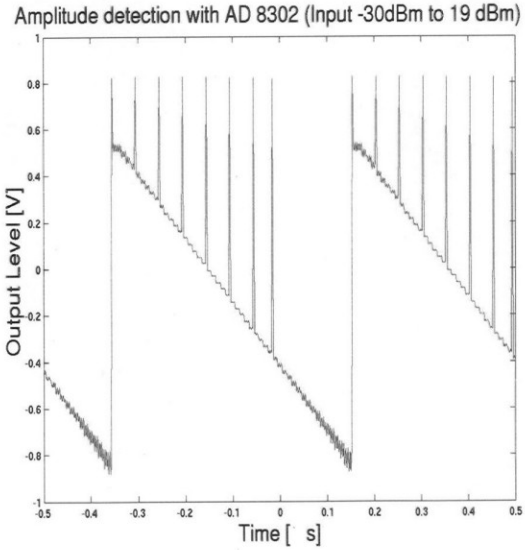
- The same detectors for forward and reflected power
- Field control with IQ detectors (AD 8347)
- Measurement of Loaded Q and detuning with logarithmic amplitude and phase detector (AD 8302)
- Modern phase detector (HMC 439) for phase monitoring
- Detector diode for amplitude monitoring

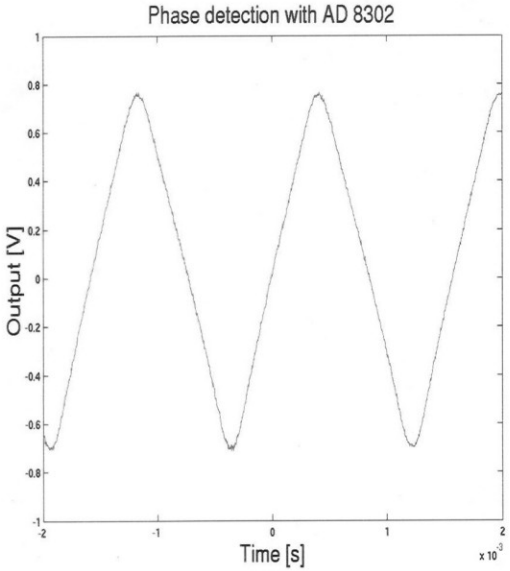
Performance of the IQ Detector



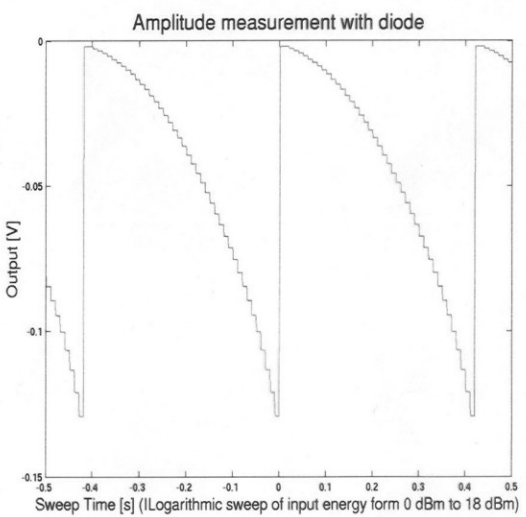


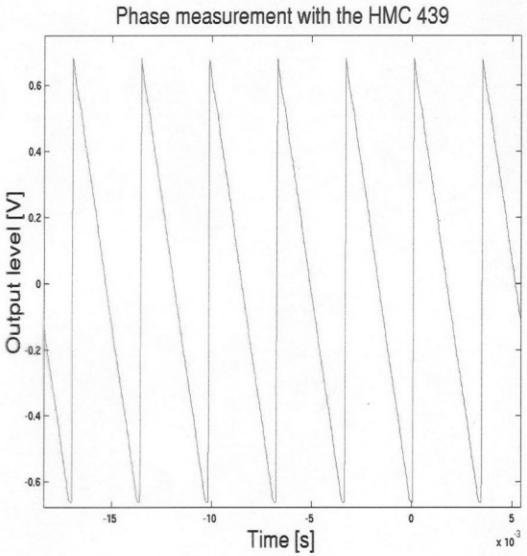
Measurement with AD 8302

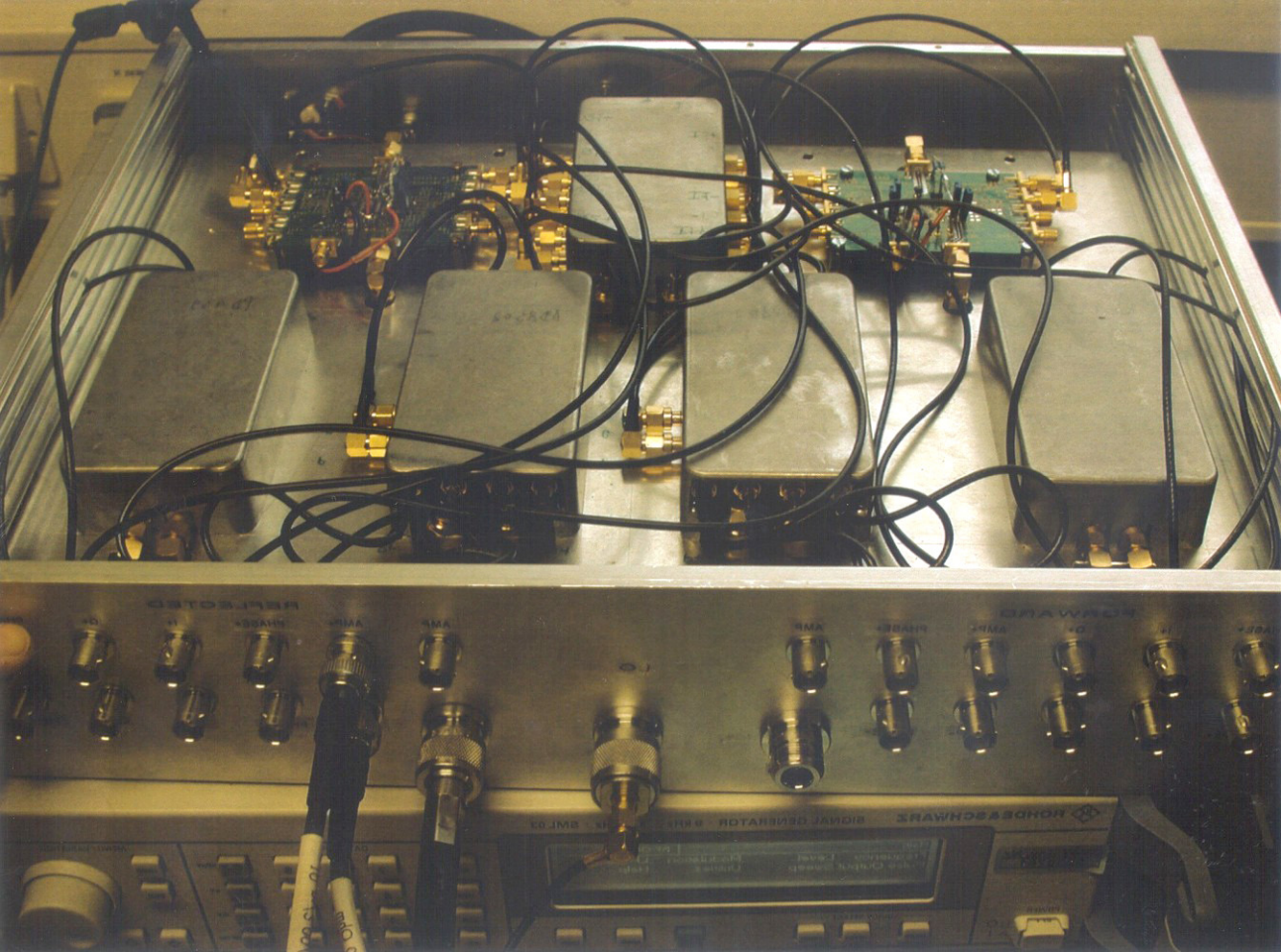




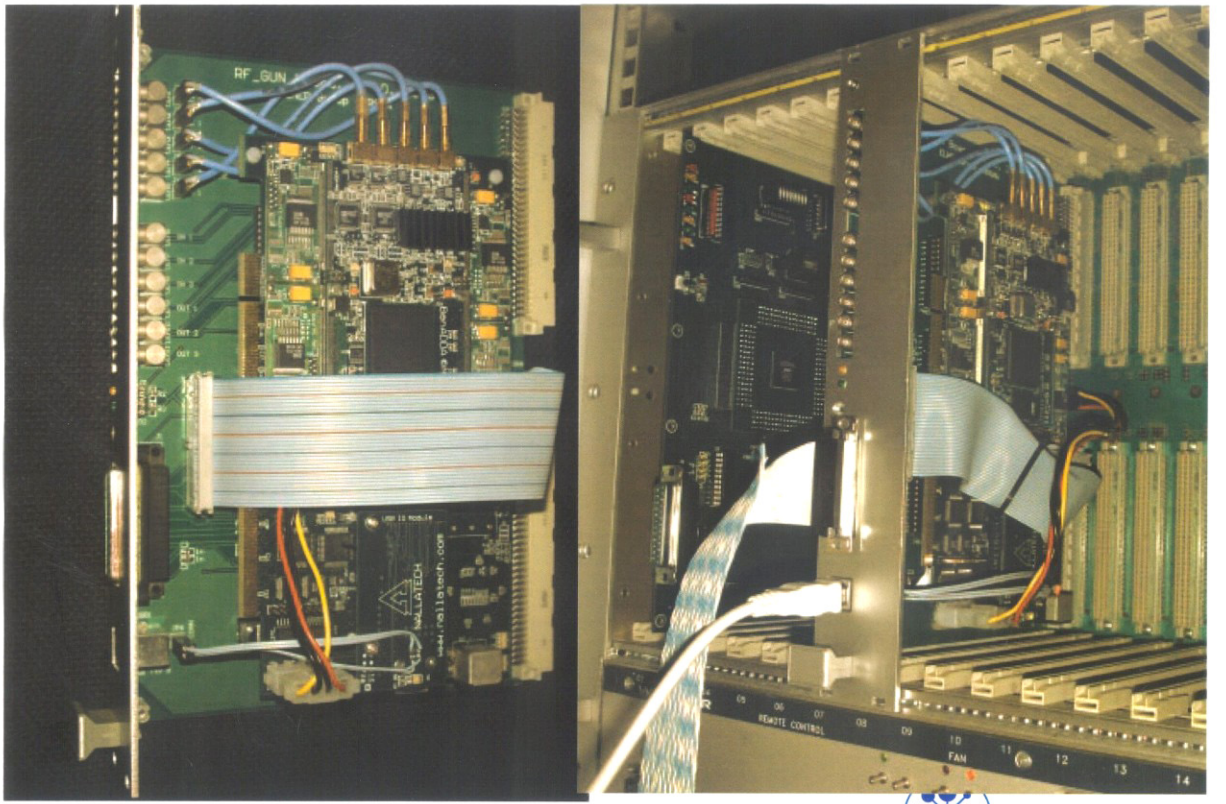
Detector diode and Phase detector



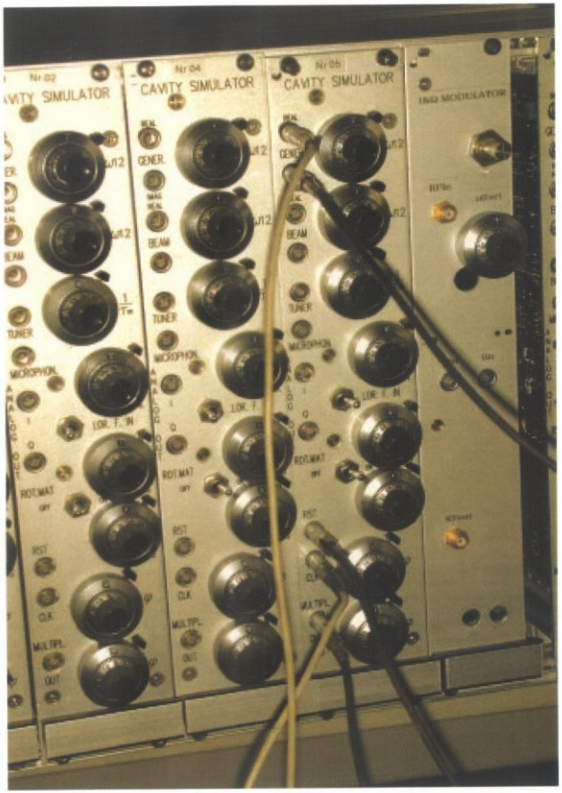


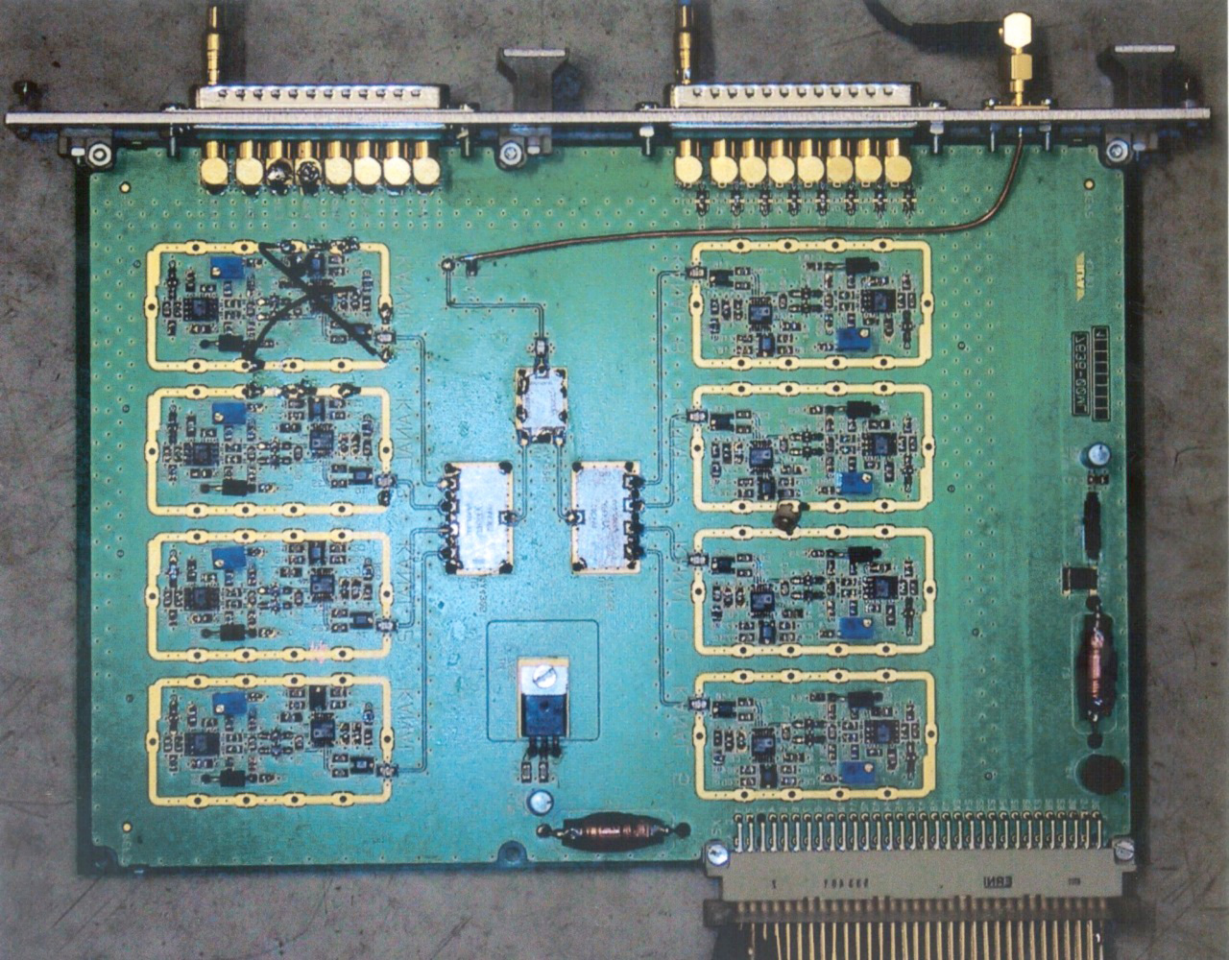


FPGA based RF Gun ControllerFPGA



Cavity Simulator





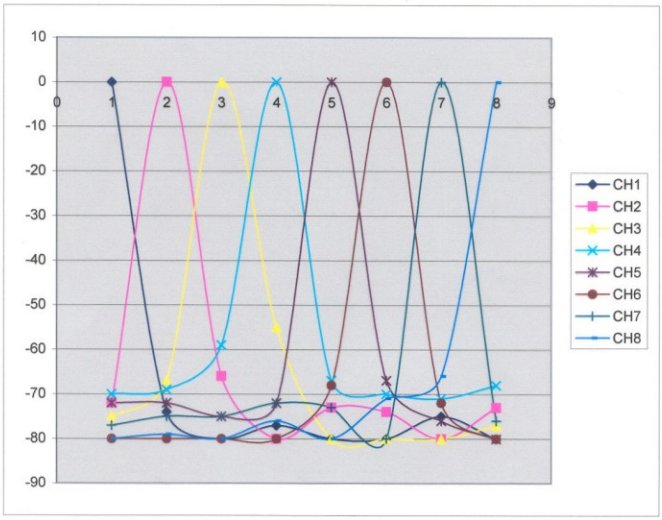
7636_00ML

LO=1.3G/ / RF=1.3G+250K

LO=-0dBm,1.3G/ / RFin=-12dBm/

Crosstalk Gesamübersicht X=Einspeisung

	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
CH1	X	-72	-75	-70	-72	-80	-77	-80
CH2	-74	X	-67	-69	-72	-80	-75	-79
CH3	-80	-66	X	-59	-75	-80	-75	-80
CH4	-77	-80	-55	X	-72	-80	-72	-76
CH5	-80	-73	-80	-67	X	-68	-73	-80
CH6	-80	-74	-80	-70	-67	X	-80	-71
CH7	-75	-80	-80	-71	-76	-72	X	-66
CH8	-80	-73	-77	-68	-80	-80	-76	X



L0=0dBm 7636_00

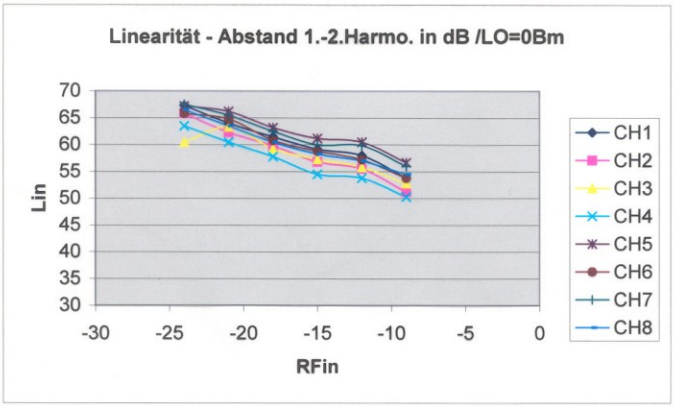
1.Harmonische

RF(db)	CH11	CH21	CH31	CH41	CH51	CH61	CH71	CH81
-9,00	5,80	6,20	6,80	8,80	5,70	5,30	5,00	8,00
-12,00	3,00	3,50	3,80	5,80	2,50	2,20	1,80	5,00
-15,00	-0,80	-0,20	0,30	2,00	-0,80	-1,20	-1,50	1,30
-18,00	-3,50	-3,20	-2,70	-0,70	-3,80	-4,20	-4,50	-1,50
-21,00	-6,50	-6,20	-5,70	-3,50	-6,80	-7,20	-7,50	-4,50
-24,00	-9,70	-9,20	-8,50	-6,50	-9,80	-10,20	-10,50	-7,50

2.Harmonische

RF(db)	CH12	CH22	CH32	CH42	CH52	CH62	CH72	CH82
-9,00	-48,00	-45,00	-46,00	-41,50	-51,00	-48,50	-51,00	-46,50
-12,00	-55,00	-52,00	-52,00	-48,00	-58,00	-55,00	-58,00	-52,00
-15,00	-60,00	-57,00	-57,00	-52,50	-62,00	-60,00	-61,50	-57,00
-18,00	-65,00	-63,00	-62,00	-58,50	-67,00	-65,00	-67,00	-62,00
-21,00	-70,50	-68,50	-69,00	-64,00	-73,00	-72,00	-73,00	-68,00
-24,00	-77,00	-75,00	-75,00	-70,00	-77,00	-76,00	-78,00	-74,00

RF(db)	CH1	CH2	CH3	CH4	CH5	CH6	CH7	CH8
-9	53,8	51,2	52,8	50,3	56,7	53,8	56	54,5
-12	58	55,5	55,8	53,8	60,5	57,2	59,8	57
-15	59,2	56,8	57,3	54,5	61,2	58,8	60	58,3
-18	61,5	59,8	59,3	57,8	63,2	60,8	62,5	60,5
-21	64	62,3	63,3	60,5	66,2	64,8	65,5	63,5
-24	67,3	65,8	60,5	63,5	67,2	65,8	67,5	66,5



Requirements for the M.O. for TTF2

- Required frequencies: 50Hz, 50Hz(TTL), 1MHz, 9MHz, 13.5MHz, 27MHz, 81MHz, 108MHz, 1.3GHz, 1.517GHz, 2.856GHz
- Required stability:

  within macropulse (1ms): 0.1ps

  integrated timing jitter (Δf=1MHz): 1ps

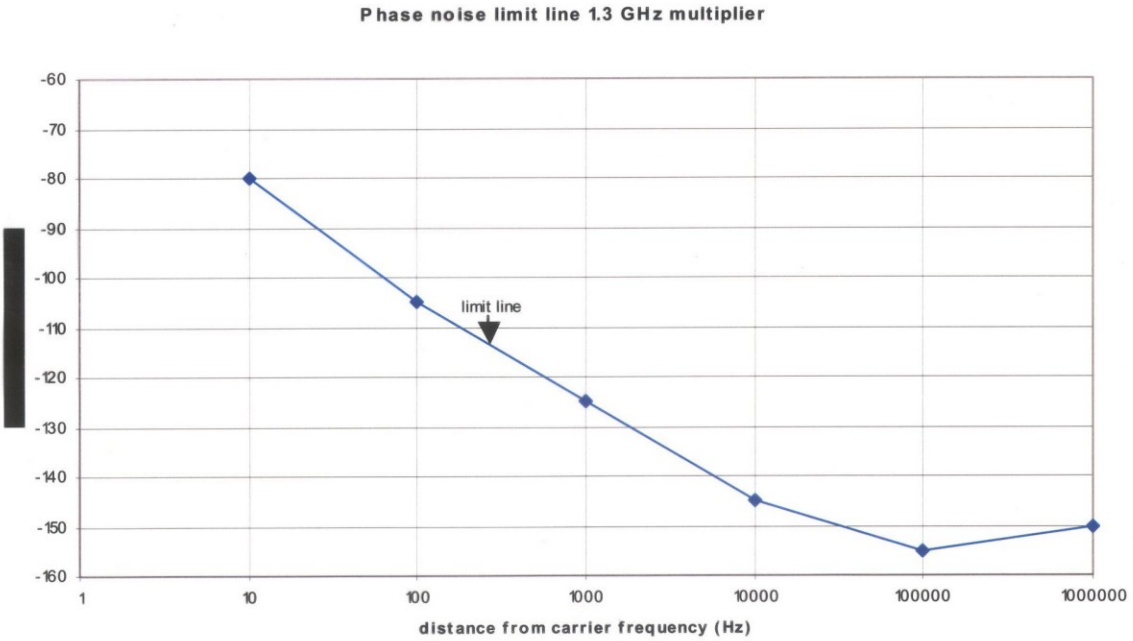
  long term: 1ps (minutes)

  2ps (hours)

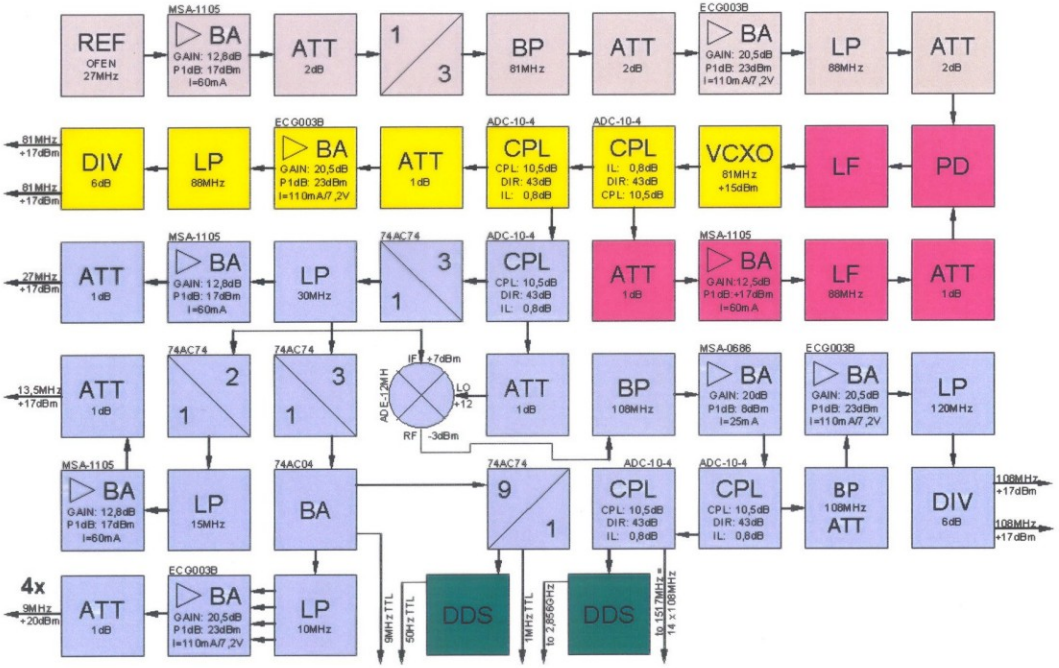
  10ps

K.Czuba, B.Lorbeer, S.Simrock, H.Weddig

Required Phase Noise Spectrum:

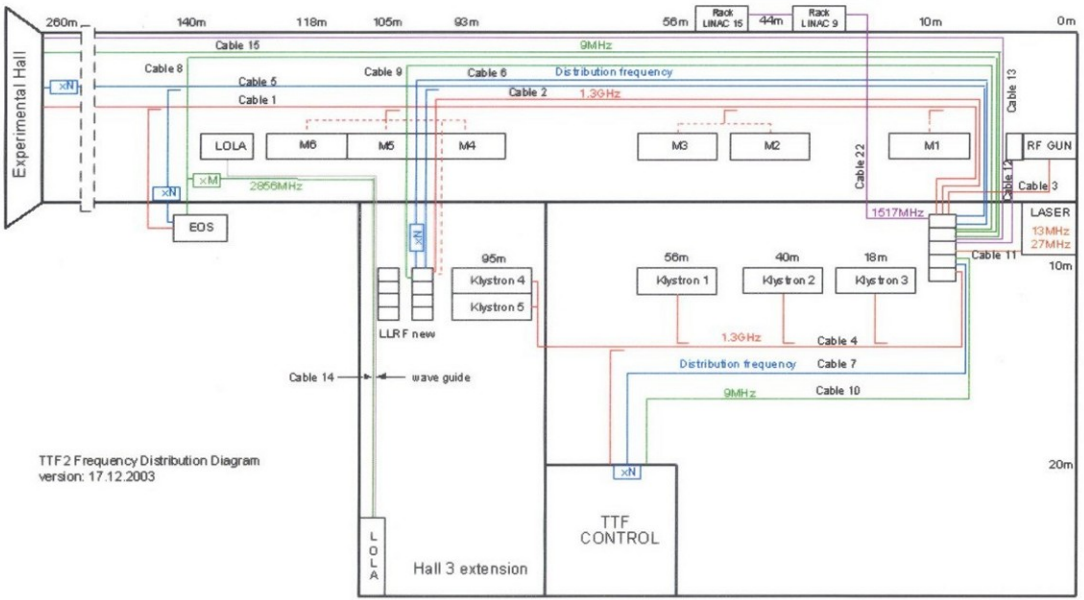


Blockdiagram of M.O.:

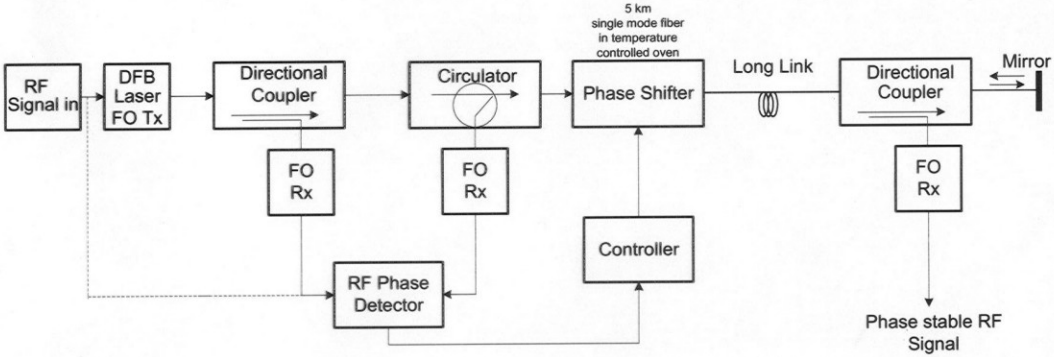


The new Master Oscillator for TTF2

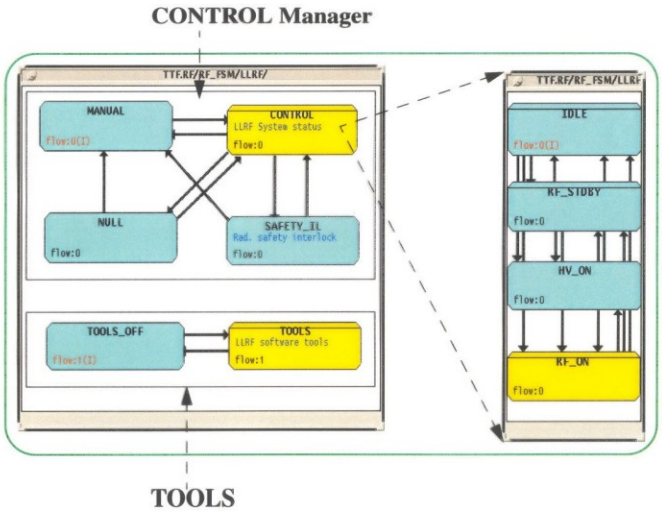
TTF2 cable distribution layout:



Fiber-optic Distribution System



Implementation of FSM Server for RF System



IDLE

Check hardware, Start-up, Check/restore/modify operational settings

RF_STDBY

Check/reset Interlocks, Find source, check limits, Collect statistics

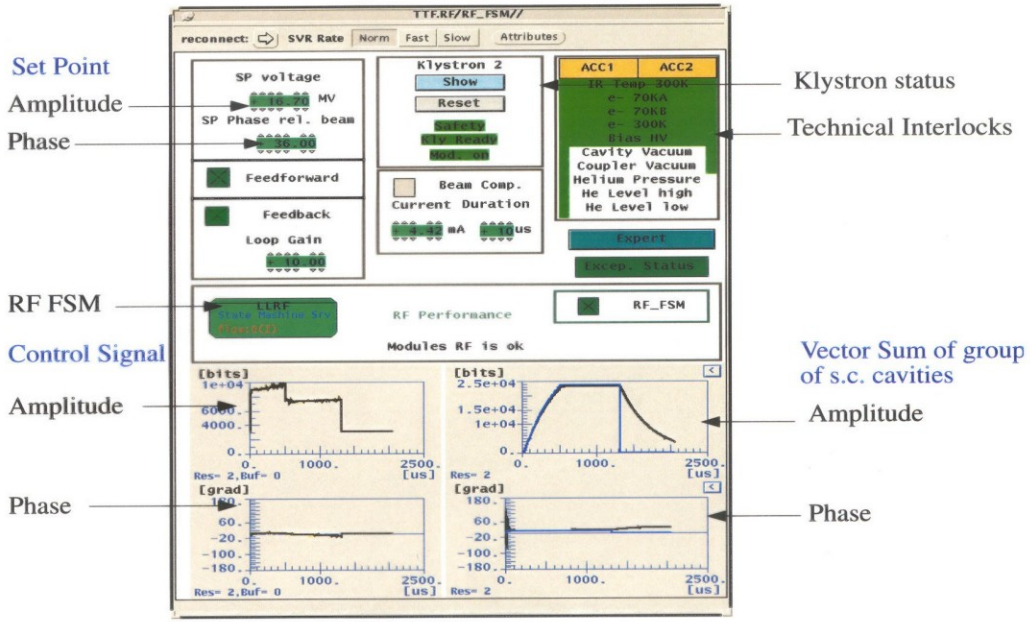
HV_ON

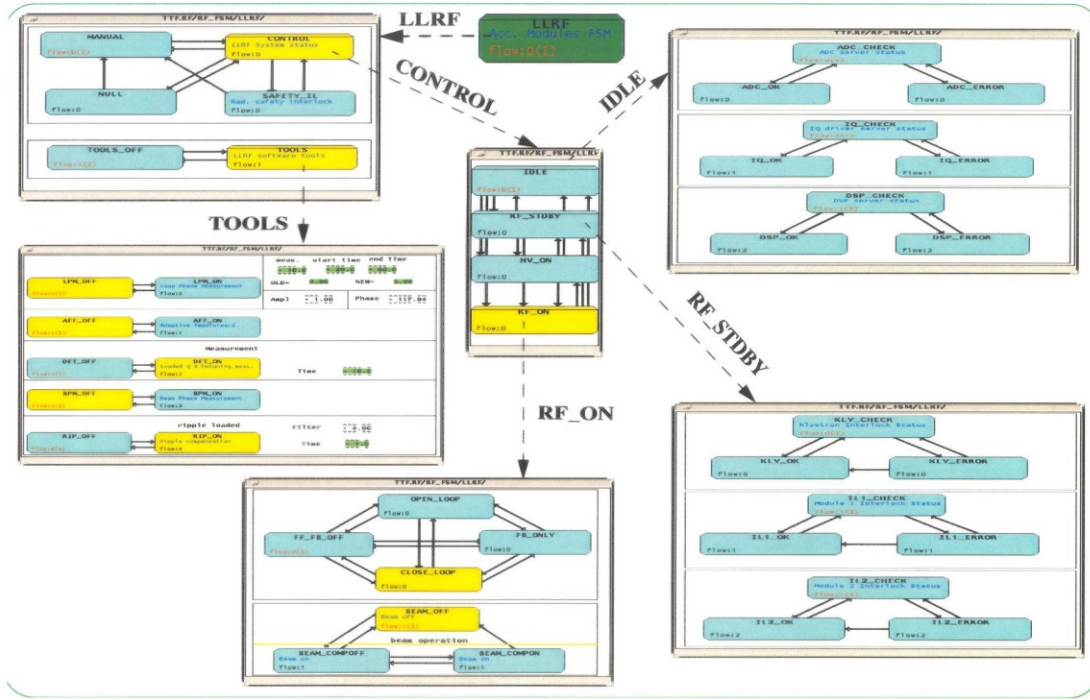
High voltage is applied, RF is not permitted

RF_ON

Adjust feedback loop, Optimize beam parameters

The main DDD panel for RF operation on the modules





Valeri Ayvazyan, 1/16/04

LLRF Team

Name	Field of Expertise
Ayvazyan, Valeri	Software, FSM, DOOCS, Controls, Applications, Linac Operation
Bienkowski, Andrej	RF Hardware, analog and digital hardware
Brandt, Alexander	Finite state machine
Bruns, Thomas	Computer (Unix) administration
Cichalewski, Wojciech Koseda, Boguslaw	FSM and applications
Czarski, Tomasz	RF Modelling, FPGA development, optimal control
Czuba, Krzysztof	M.O. and Distribution, Fiber optic link
Eints, Frank	Hiwi
Felber, Matthias	Hiwi
Froelich, Thomas	Installation, Documentation, Maintenance
Hensler, Olaf	DOOCS control system (deputy of K. Rehlich)
Grecki, Mariusz	TUL-DMCS group leader
Ignachin, Nikolai Sytov, Sergei	Analog, digital, and rf electronics
Jezynski, Tomasz	FPGA control for RF Gun/XFEL
Kierzkowski,	FPGA hardware and programming
Kotthaus, Daniel	RF Gun Control
Lilje, Lutz	Piezo tuner, high gradient cavities
Lorbeer, Bastian	Master Oscillator and Distribution
Makoswki, Dariusz	Radiation issues for electronics
Matsumoto, Toshiyushi	RF System Modelling, LLRF Development
Moeller, Guenter	RF Hardware, Downconverter, vector-mod, rf-gate
Pawlik, Pawel	Single bunch transient
Petrosyan, Gevorg	DSP programming, DSP code and server
Petrosyan, Lyudvig	Timing expert, ADC server
Posniak, Krzysztof	FPGA hardware and software
Pucyk, Piotr	DOOCS control of FPGA
Rehlich, Kay	DOOCS control system (group leader)
Romaniuk, Ryzard	WUT-ISE group leader
Rutkowksy, Peter	DOOCS control of FPGA
Rybka, Dominik	Radiation damage to electronics
Schrader, Matthias	RF Control
Sekalski, Przemyslaw	Piezotuner and control
Simrock, Stefan	LLRF (group leader)
Vetrov, Piotr	DSP hardware (DSP board, Gigalink, ADC, DAC)
Wagner, Richard	Hera Protonen HF, NT Administration
Weddig, Henning	RF Hardware, M.O. and Distribution, Analog and digital electronics, RF Measurements
Zabolotny, Wojciech	FPGA hardware and programming

Summary

- Commissioning of LLRF for TTF II is well underway
  - Feedforward for ACC 4,5,6 (old IQ drivers) available
  - New C67 based DSP System for RF Gun and ACC1 under commissioning. In operation with cavity simulator
  - New "field" detectors for RF Gun
  - Prototype of FPGA based controller and cavity simulator
- Master oscillator and frequency distribution are presently being installed
  - New frequencies (2856 MHz, 13.5 MHz)
  - Temperature stabilized coaxial distribution
  - Highly stable fiber optic monitoring system
- Automation of LLRF operation under development