LLRF Feedback Controller Design for ACC 1

Saulat Chughtai & Gerwald Lichtenberg

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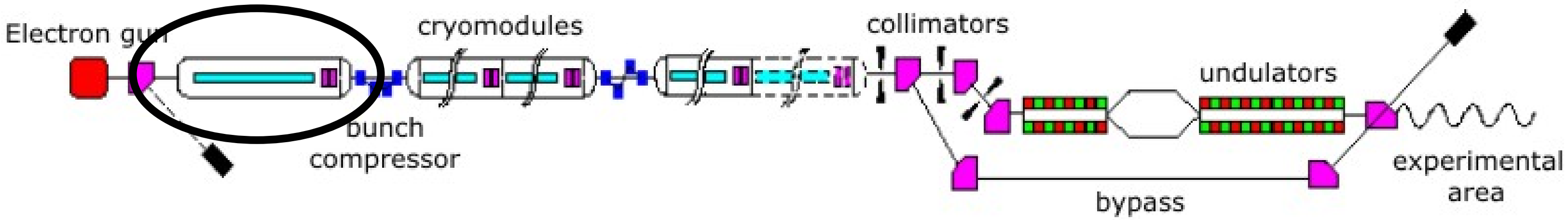
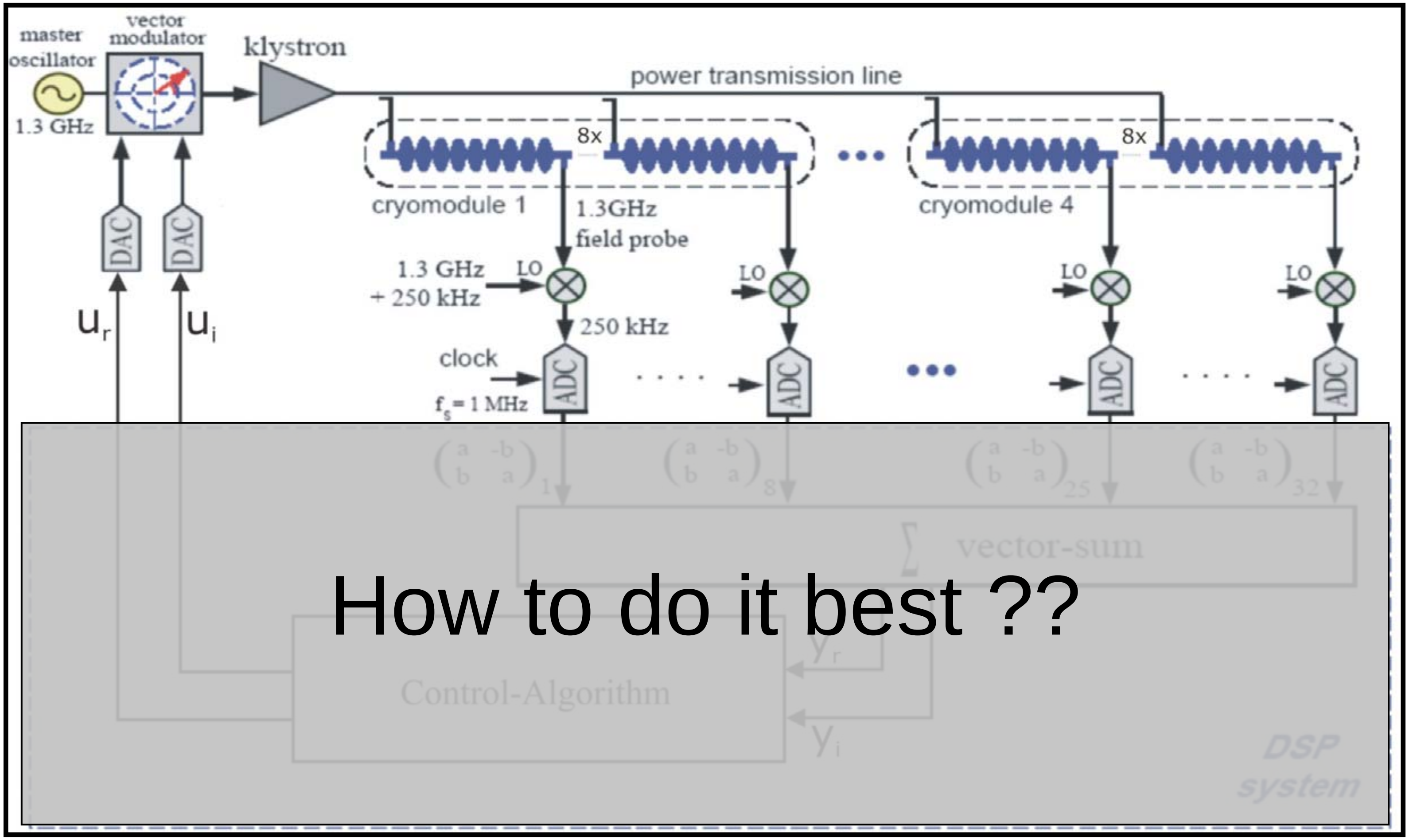
VUV-FEL - Structure



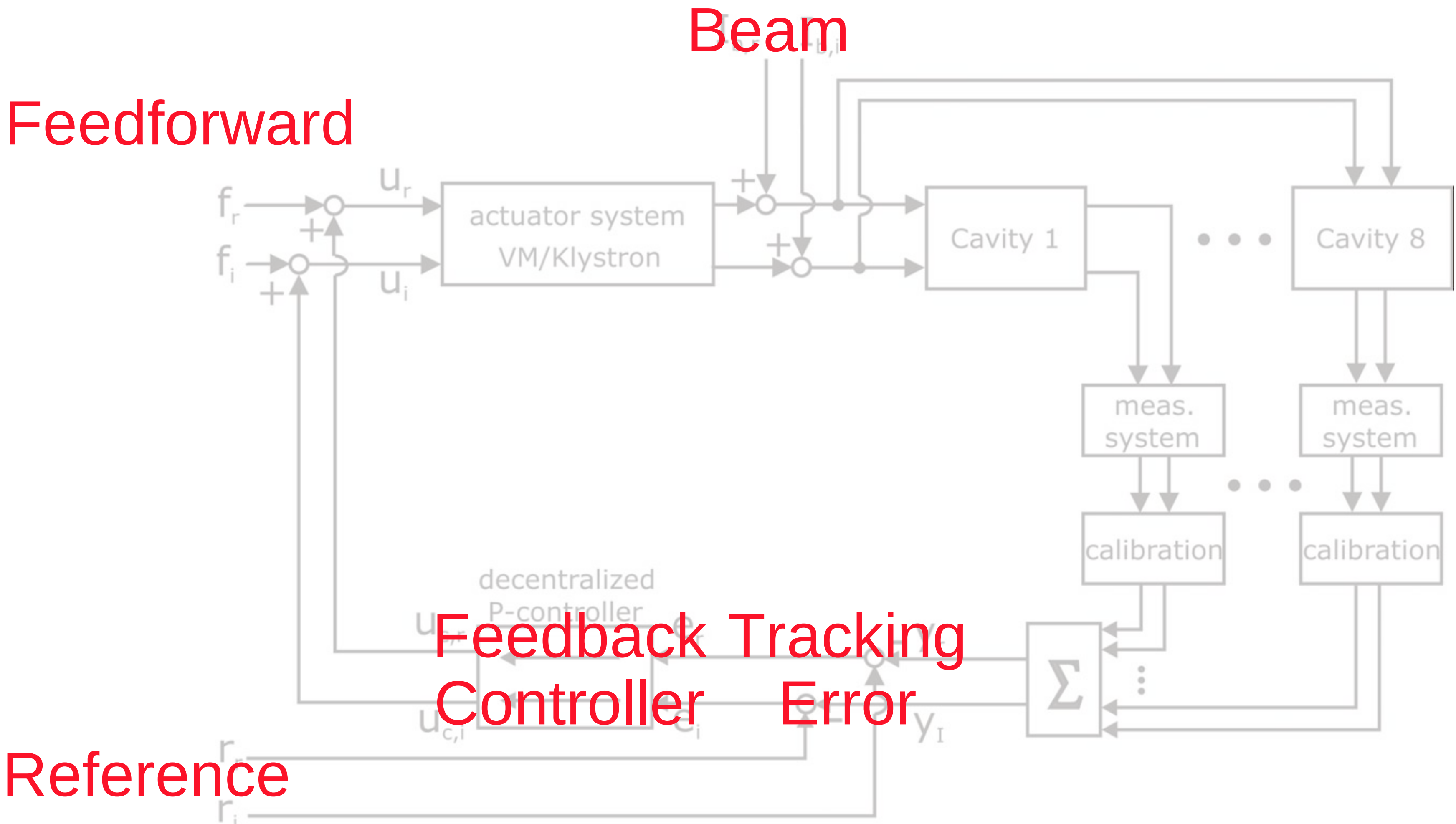
ACC 1

Low Level RF-System



How to do it best ??

Current LLRF Control Structure



Feedforward and Feedback Control

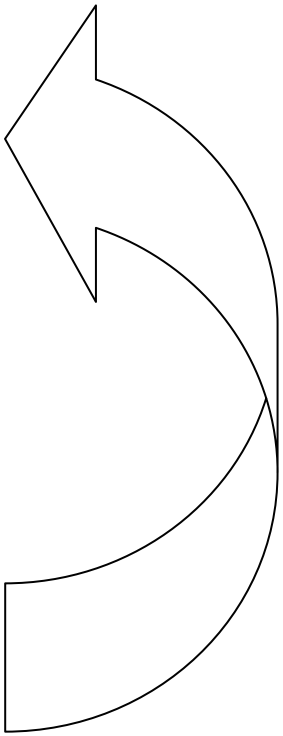
- Feedforward
  - No possibility to react on disturbances
  - Applicable for well known systems behaviour

- Feedback
  - Can attenuate disturbances
  - Robustness w.r.t parameter changes

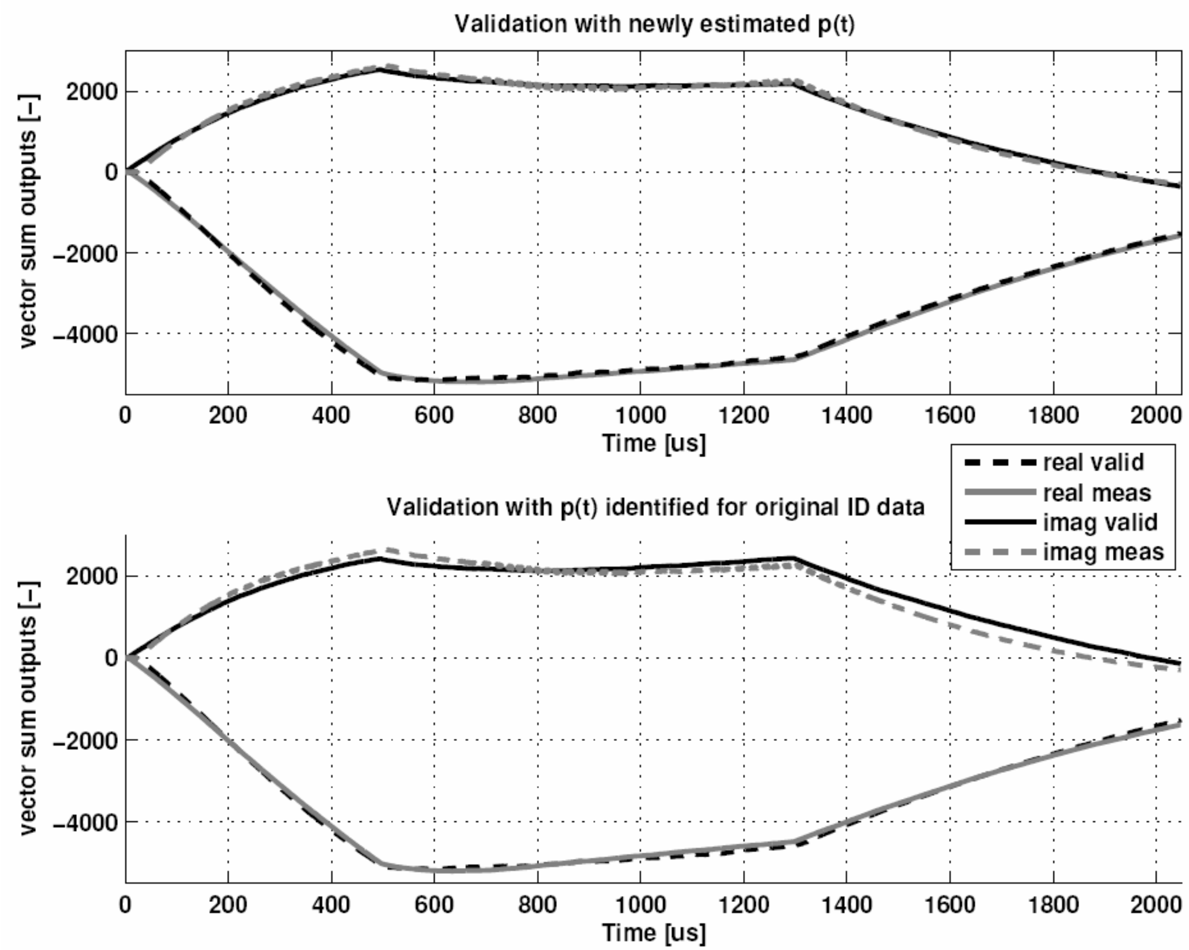
- Design inner prior to outer loops
  - First steps: inner feedback loops !

Controller Design – Standard Method

- Modelling / Parameter Identification
  - Linear/nonlinear, discrete/continuous time models, …
  - Validation
- Design Control Loop Structure
  - Decentralized, MIMO, Robust, adaptive, …
- Choose Controller Structure
  - E.g. linear, PID, 2nd order discrete time, ...
- Find Parameter of Controller Components
  - Rules of thumb, Optimization, Tools based, …
- Test Closed Loop
  - Simulation
  - Experiments



Modelling & Validation



[Koch 2005]

Control Loop & Controller Structure

- Experiences show that 3 parts should be used together
  - Feedforward Tables: adapted to current detuning situation
  - Reference Tables: tuned to basic system and setpoint properties
  - Feedback Controller: for disturbance attenuation
- New SIMCON developments [Buchholc, Koch et al ..]
  - Feedback controller can be dynamic, not only proportional
  - Feedback controller need not to be decentralized
  - Parameters have to be found (robust / adaptive)
- Open Problems
  - Calibration: belongs to the controller & is tuned manually
  - Vector sum: Only solution to the problem of underactuation?
  - Feedforward tables: Adaption based on measurements?

March 2006 Shifts

- 2 main and 4 parallel studies
- SIMCON Implementation of 2nd order MIMO controller
  - Thanks to S. Buchholc, W. Kopreck et al … !
  - Not installed permanently
  - At the beginning of each shift calibration necessary

March 2006 Shifts

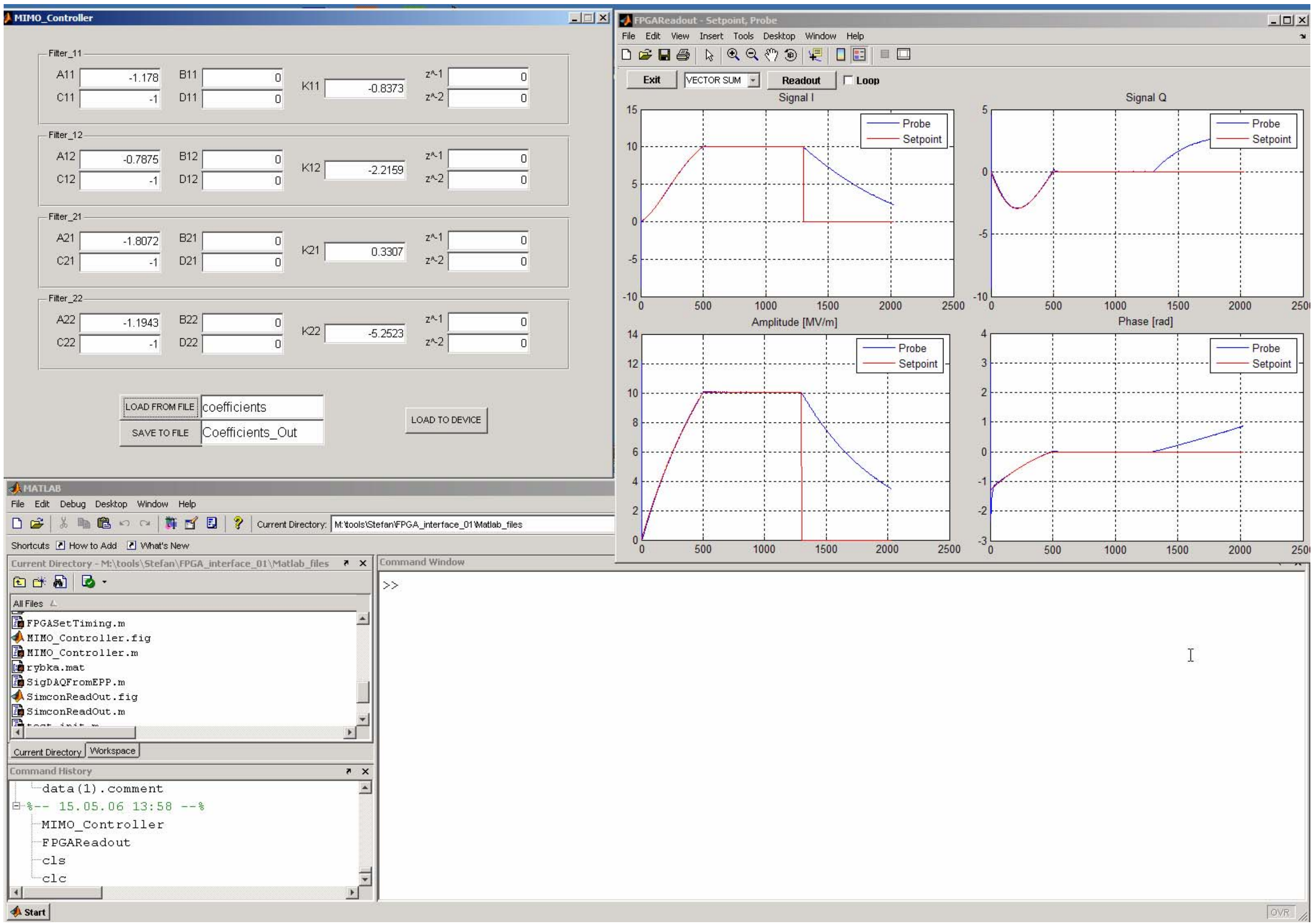
Main Aims During March Shifts:

- Check performance of SIMCON software
  - Limitations of the board
  - Data acquisition for modeling
  - Saturation limits
- Check response of dynamic controllers

Structure:

$$K(z) = \begin{bmatrix} K_{11}(z) & K_{12}(z) \\ K_{21}(z) & K_{22}(z) \end{bmatrix}, \qquad K_{ij}(z) = k_{ij} \frac{1 + a_{ij} z^{-1} + b_{ij} z^{-2}}{1 + c_{ij} z^{-1} + d_{ij} z^{-2}}, \forall i,j = 1,2$$

Controller Parametrization Panel



March 2006 Shifts

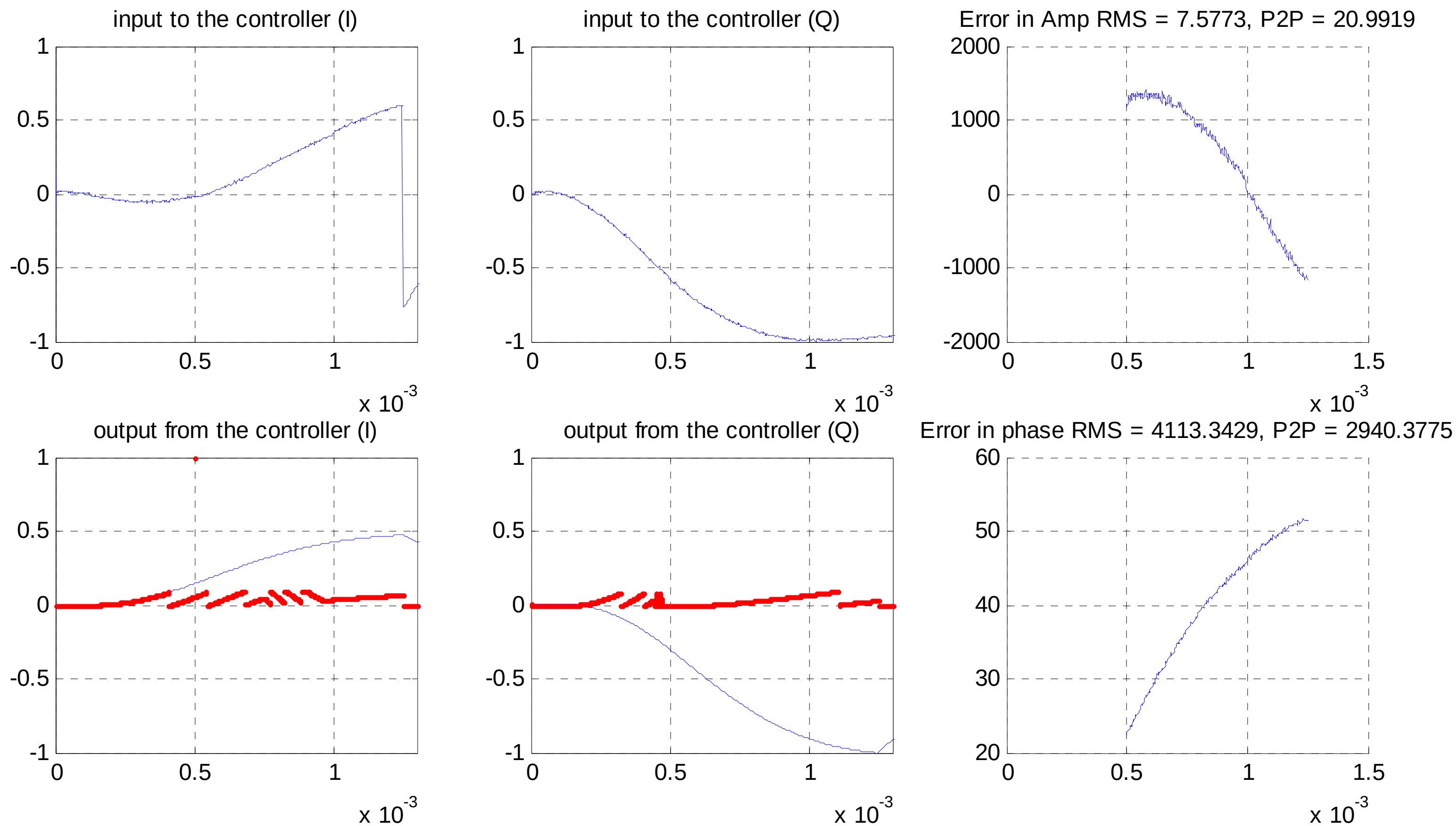


Figure.1 Saturation of states in implemented controller (red)

March 2006 Shifts

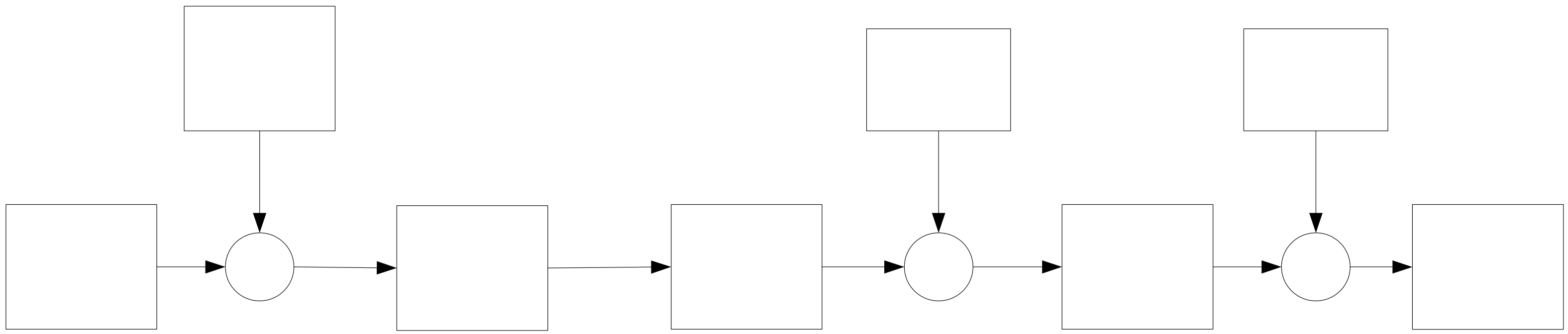


Figure. 2 controller structure in SIMCON board

To avoid saturation of states slide buttons are introduced in controller input screen.

Controller Design Approach

1. Single P controller
2. Full P controller
3. Decentralized dynamic controller
4. Full MIMO dynamic controller
5. Robust or gain-scheduled controller

March 2006 Shifts

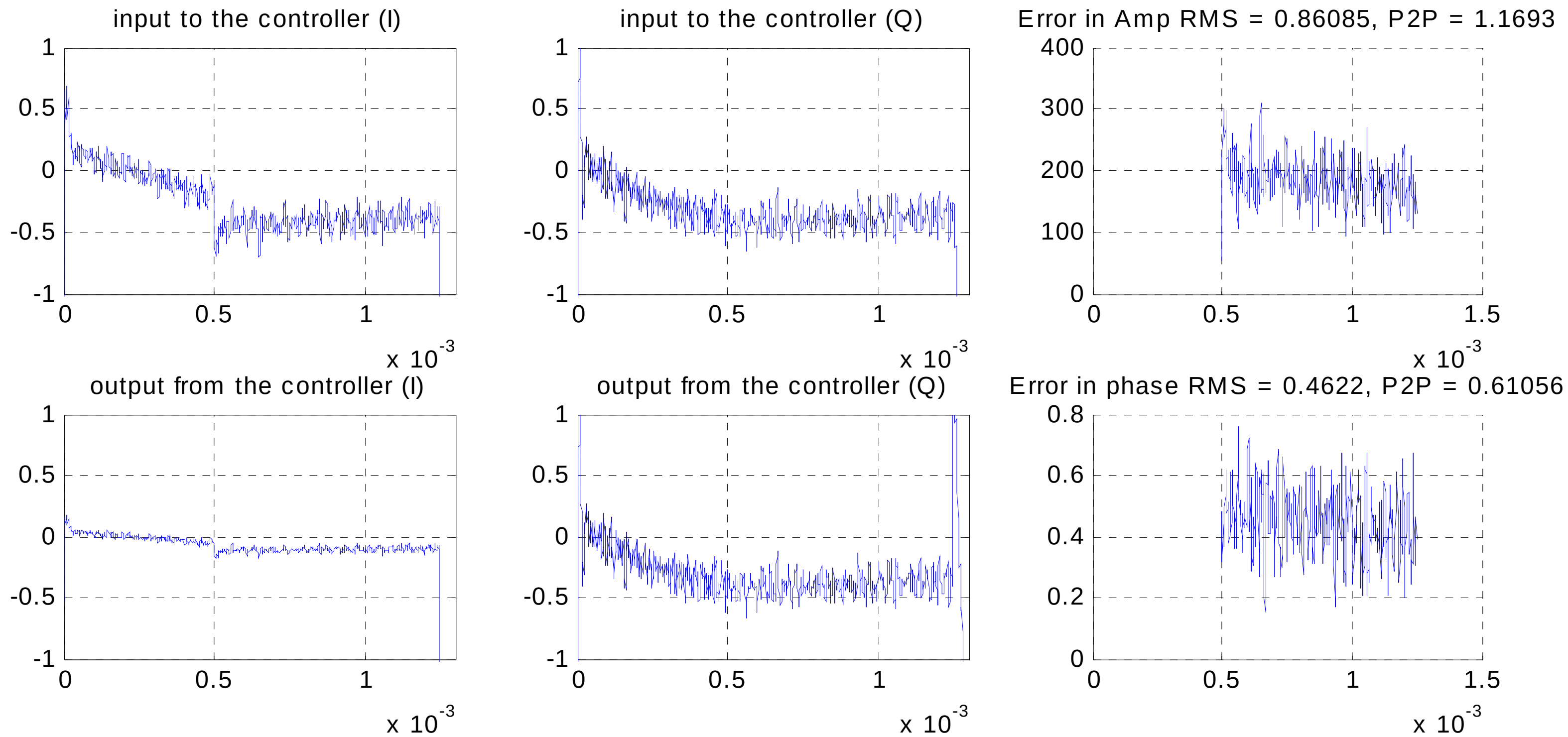


Figure.3 System response to full P controller.
(single gain resulted in RMS value of ~1.24 deg)

March 2006 Shifts

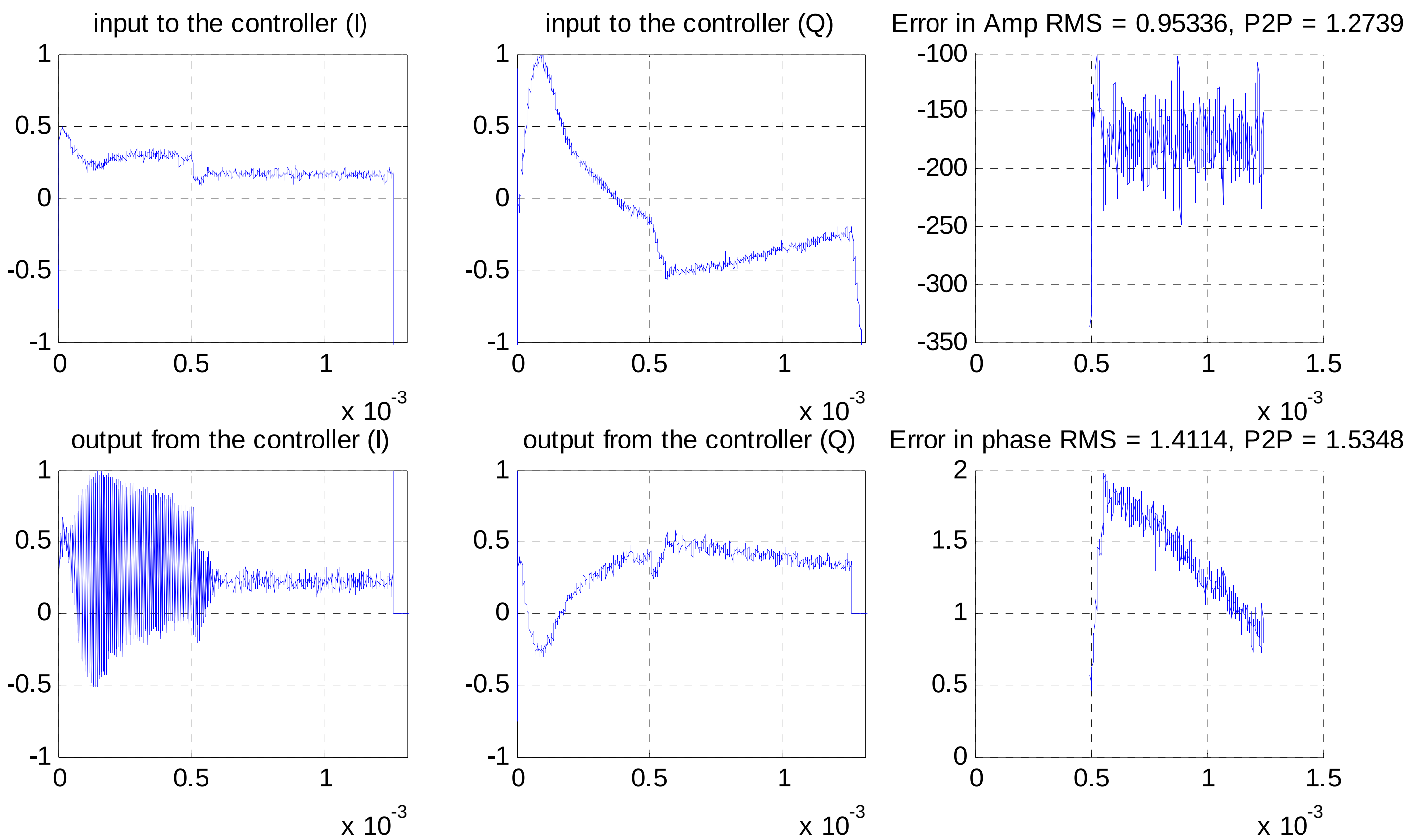


Figure.4 System response with dynamic controller (with only K11 dynamic).

Summary

- Software for SIMCON board is tested.
  - Cannot apply test signal for modeling
  - State saturation problem is encountered and rectified.
  - Can measure actual data.
  - No 250 kHz noise
- Full P controller is tuned which shows improvement in system response.
- Dynamic controller is designed and tested in closed loop.

Work in Progress

- 6 / 2006
  - Further tests with 2nd order feedback controller
- 7-12 / 2006
  - Better models for disturbances
  - Adaption / Robustness of feedback controller / Antiwindup?
  - Include Piezo Actuators in Control Loop Structure ?
- 1-6 / 2007
  - Adaption of Feedforward / Reference Tables
  - Iterative learning control ?
- 7-12 / 2007
  - Other ACCs
  - Integration test in closed loop
- 2008
  - Increasing setpoint gradient

Thank you for your attention !

- Discussion -