Control algorithm tests using virtual CW SRF cavity

Universidad del País Vasco / Euskal Herriko Unibertsitatea — eman ta zabal zazu

HZB Helmholtz Zentrum Berlin

Josu Jugo, Ander Elejaga, University of the Basque Country UPV/EHU, Leioa, Spain

Pablo Echevarria, Helmholtz Zentrum Berlin, Berlin, Germany

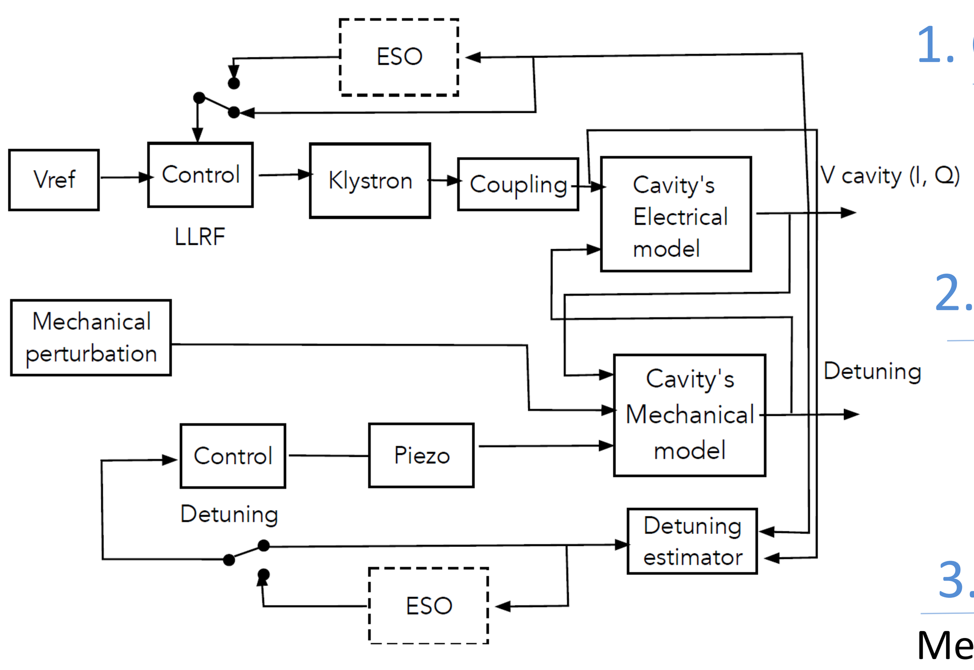
1. Objectives

The main objective is the development of a simulation environment based on a virtual CW SRF cavity for the test and comparison of the performance of different control algorithms:

- Test control algorithms for the LLRF system of the cavity: a PI and an ADRC controller.
- Compare the performance of different controllers on suppressing unwanted microphonics.
- Analyze the effect of the mechanical delay of the piezo tuner.

2. System description

The system includes the electrical and mechanical model of the cavity, the RF part (Klystron and coupling) and a piezo tuner, considering a time delay and the mechanical effect of such tuner in the cavity.



1. Cavity's electrical model

	Q_o	$R/Q\,(\Omega)$	f_{RF} GHz
Tesla cavity	$5.0\,10^{10}$	900	1.3

2. Cavity's mechanical model

	Mode 1	Mode 2	Mode 3	Mode 4
ω_n	262	589	1079	1216
δ	0.0025	0.0045	0.0036	0.0047

3. Piezo-tuner

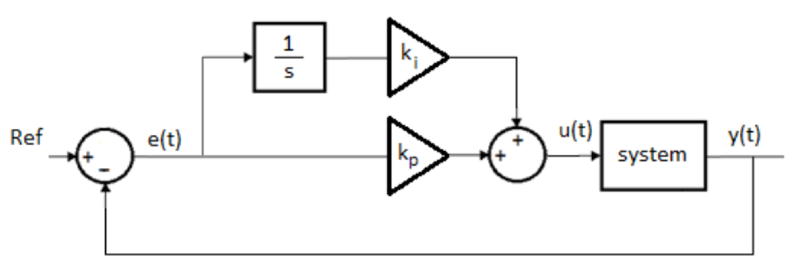
Mechanical delay of 115 microseconds

3. Control algorithms

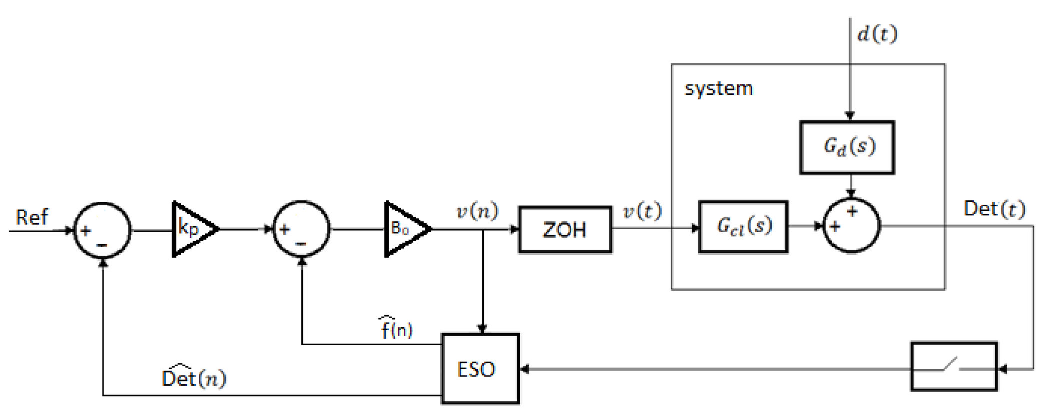
Three different control algorithms have been initially considered:

1. PI control

The PI has been used as the basic controller in both LLRF system and tuner's loop



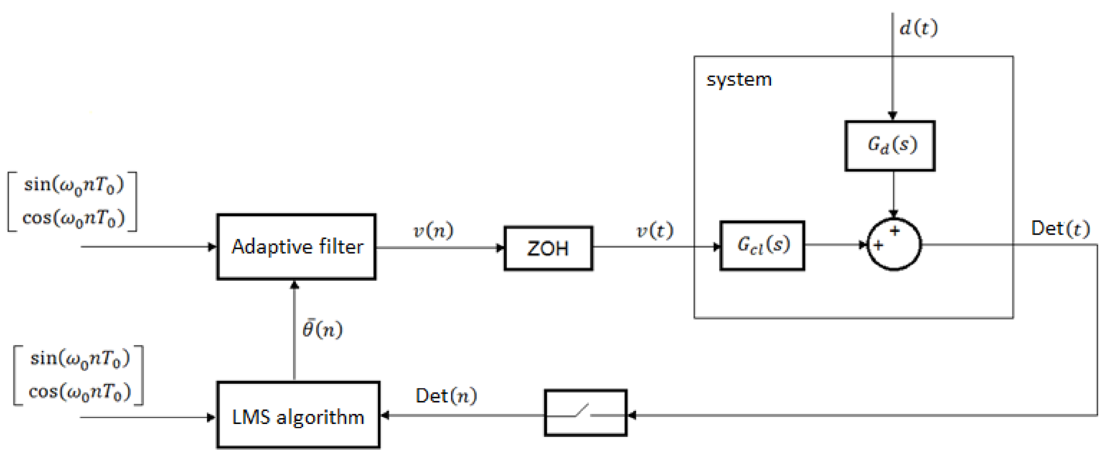
1. Active Disturbance Rejection Control (ADRC)



A linear ADRC has been implemented in both control loops to compare its performance with the basic PI

3. Adaptive Feedforward (AFF)

An AFF algorithm has been implemented in the piezo tuners loops as an addition to the PI/ADRC, to suppress located microphonics.



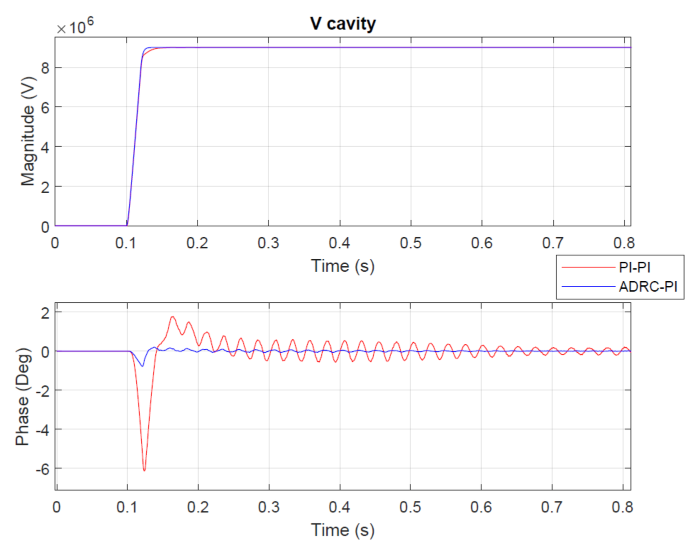
4. Preliminary Results

Different scenarios has been considered, combining the control algorithms in both control loops:

- **Scenario 1**: A basic PI in both the LLRF and the tuner's loop
- **Scenario 2**: An ADRC in the LLRF system and a PI controller in the tuner's loop
- **Scenario 3**: An ADRC in both control loops
- **Scenario 4**: A PI controller in the LLRF system and an ADRC in th tuner's loop
- **Scenario 5**: An ADRC controller in the LLRF system and a PI+AFF controller for the tuners loop

The most relevant results are shown below:

Cavity loading



The ADRC has proved to have a very good behaviour for the LLRF system. It achieves a smoother cavity load and a much better phase stability in the cavity's voltage (<0.01 degree). Moreover, its control signal is smaller than the one achieved with the PI controller.

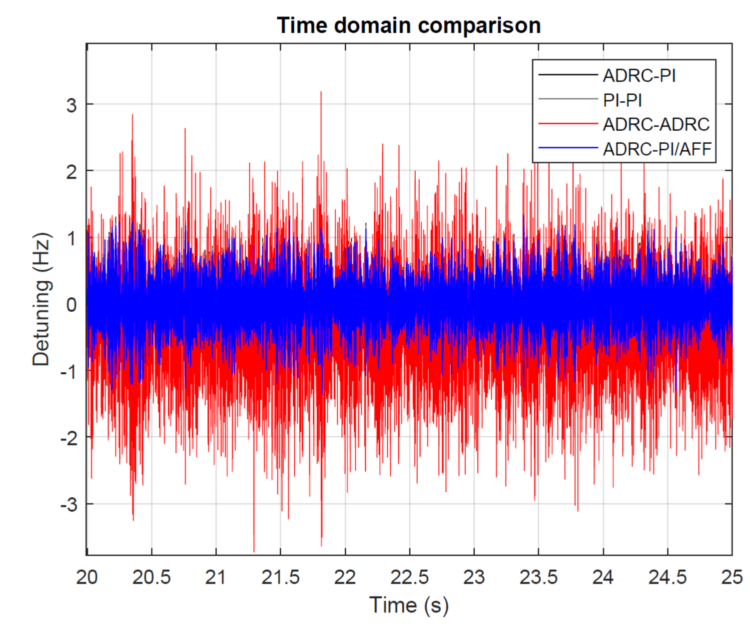
Cavity Detuning

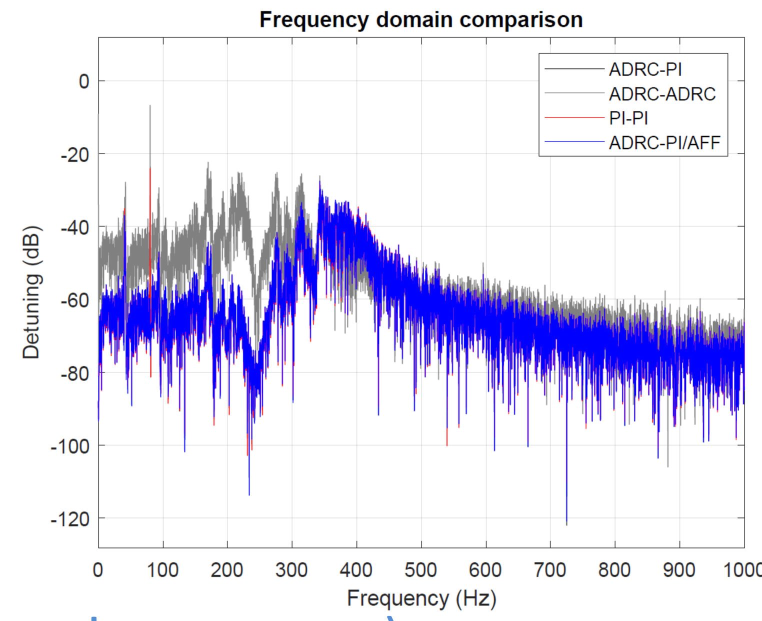
For the detuning control, the PI controller happens to offer better performance.

It reduces down the detuning to 2 Hz (peak to peak), while the ADRC is not capable of getting it down to 5 Hz.

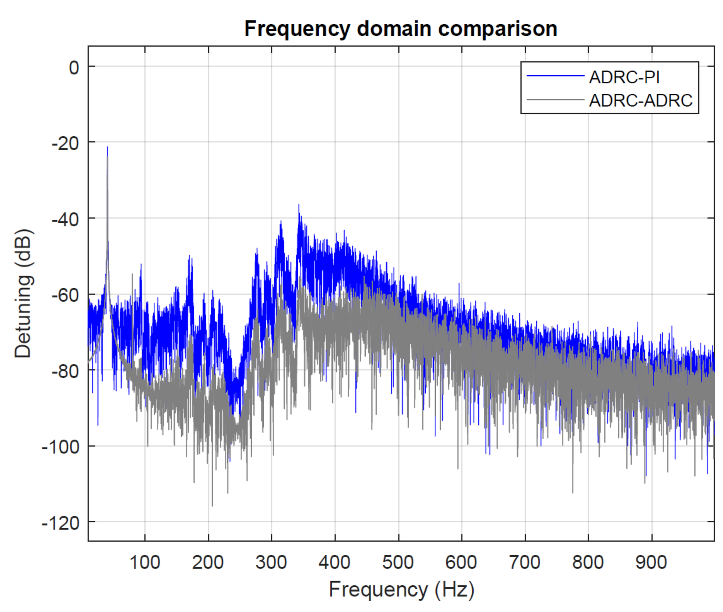
As it is shown in the second graph, the addition of an AFF controller enhances the performance of the PI, reducing the 80 Hz microphonics to almost zero.

It has been found that the mechanical delay of the actuator affects more harshly to the ADRC than to the PI.





Cavity Detuning (no delay on the actuator)



While the PI controller maintains its performance, the detuning reduction achieved by the ADRC improves in almost 40 dB.

This fact demonstrates the potential of the ADRC controller and the significant influence of the delay on it, which will be studied in more detail.

5. Conclusions

- The use of virtual cavities is a powerful design strategy that speeds up the development and improvement of SRF cavity's support systems. Those virtual cavities provide a realistic simulation environment in which rapidly test different ideas such as control strategies and so forth.
- It has been shown that the ADRC algorithm is a highly effective technique to utilize in the LLRF system, but it's performance suffers when a significant delay comes into play. Simultaneously, it has been shown that the AFF controller is capable of effectively suppressing constant frequency microphonics.
- It has been proved that the actuator's delay represents a big limitation for the ADRC to control and suppress microphonics. A further research regarding this subject is advisable, analyzing more advanced ADRC designs to deal with this issue in a more convenient way.
- The difference between the perturbation dynamics and the dynamics seen by the actuator (the non-collocated control problem) is an issue to consider and study in detail in future work.