MODIFIED ACTIVE DISTURBANCE REJECTION CONTROL FOR MICROPHONICS REDUCTION IN SRF CAVITIES

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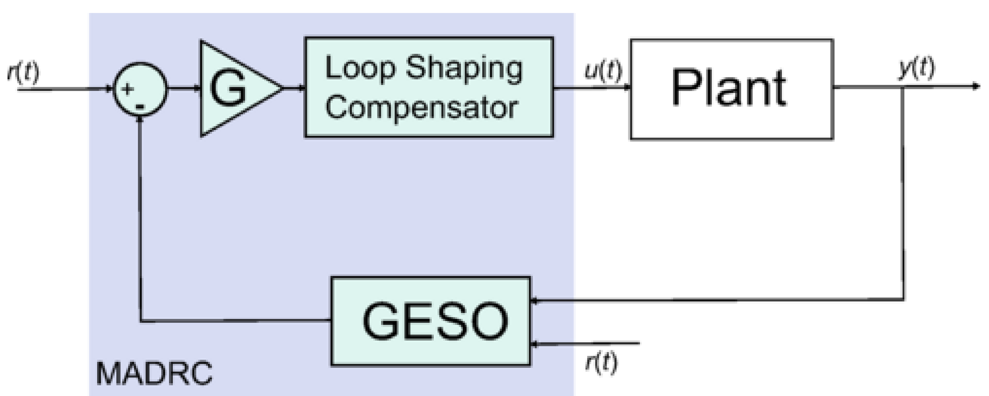
ABSTRACT: In low beam loading applications, operating SRF cavities with high loaded quality factors is currently one of the main efforts in order to reduce the electric power needed for particle acceleration (1). This reduction is a key factor for current and future facilities as it 1) decreases the initial invest (tube based amplifiers can be substituted by solid state amplifiers) and 2) reduces the plug power, lowering thus the operation costs and making the accelerators more sustainable. In this sense, controlling the microphonics detuning of the SRF cavities is fundamental to allow high QL operation. Here we present the results of a modified Active Disturbance Rejection Control used to drive the piezoactuators feedback in a TESLA cavity at HZB's HoBiCaT teststand.

Detuning feedback in SRF cavities

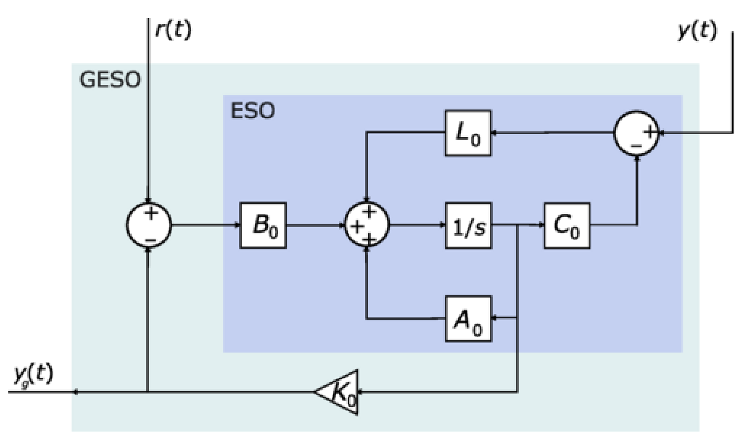
- **Feed-forward** systems are commonly used to correct vibrations whose **frequency is fixed and localized.**
- In the case of **low-frequency stochastic disturbances**, the use of **feedback control systems is necessary.**
- With PID controllers, at *f>10Hz*, the tuner-cavity system typically has **mechanical eigenmodes** that introduce steps in the phase response which may possibly lead to positive feedback and **instability** even at modest gains.
- **Active Disturbance Rejection Control (ADRC)** as an alternative to PIDs.

Modified ADRC

- **Generalized Extended state observer (GESO)**, which estimates the external disturbances and considers the internal dynamics as another disturbance.
- **Time delay** is an important limitation.
- A **Modified ADRC** scheme was introduced in (2) to increase the delay stability margin.
- **Loop Shaping filters** improve further the controller bandwidth



Structure of the novel MADRC composed of a loop shaping compensator and a generalized ESO. The signals r(t) , u(t) , and y(t) are the reference signal, the control signal, and the system output, respectively, (3).



Representation of the structure of the GESO in which the relation with the original ESO is shown. The signals r(t), u(t), and y(t) are the reference signal, the control signal, and the system output, respectively, (3).

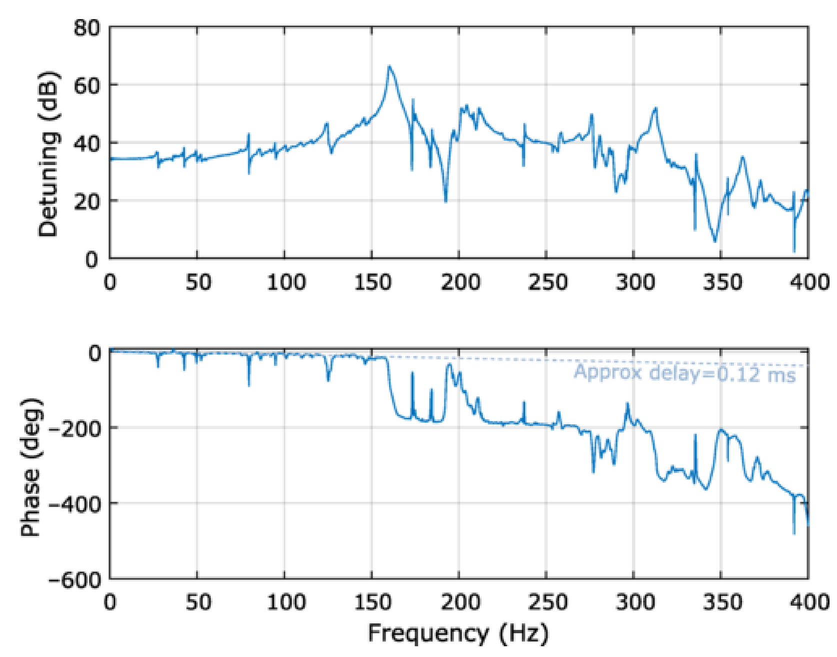
1.- Easier to analyze the open-loop frequency response of the system, thus locating the frequency ranges in which the closed-loop system has low-relative stability or is directly unstable
2.- By means of the loop shaping compensator, it is possible to modify the amplitude and phase of the system in that problematic frequency range to increase its relative stability

Designing methodology

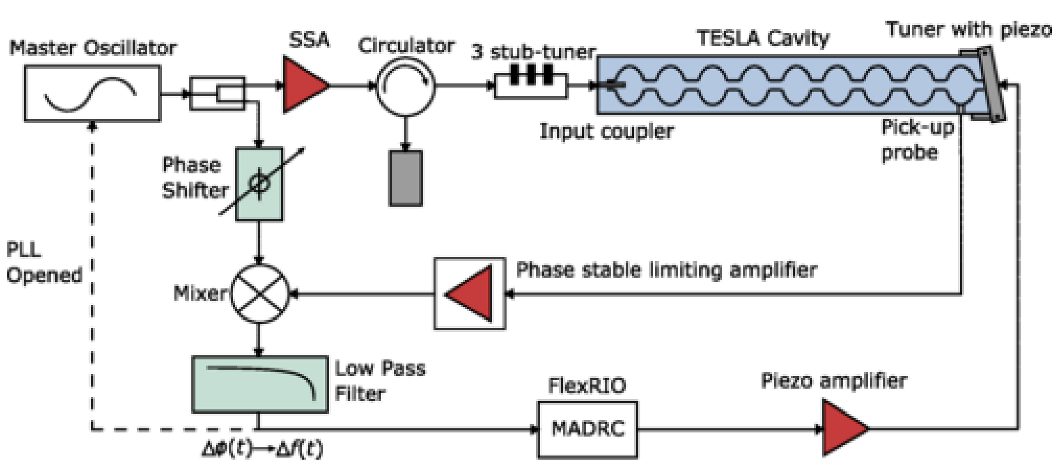
1.- Select the bandwidth of the observer, ωe:
- Determines the frequency range in which the controller acquires information
- $\uparrow \omega e \rightarrow \downarrow$ stability
- Rule of thumb: a decade larger than the disturbance to be controlled.

2.- Set the bandwidth of the controller, ωc.
3.- Start with almost no gain G and gradually increase it until the desired dynamics are fulfilled.
- If this is not possible: measure the frequency in which the instability occurs and introduce a loop shaping filter.

Tests with a TESLA cavity



Bode diagram of the transfer function that relates the piezo drive signal with the detuning, for the system composed by the Saclay-II tuner and the TESLA cavity, (3).

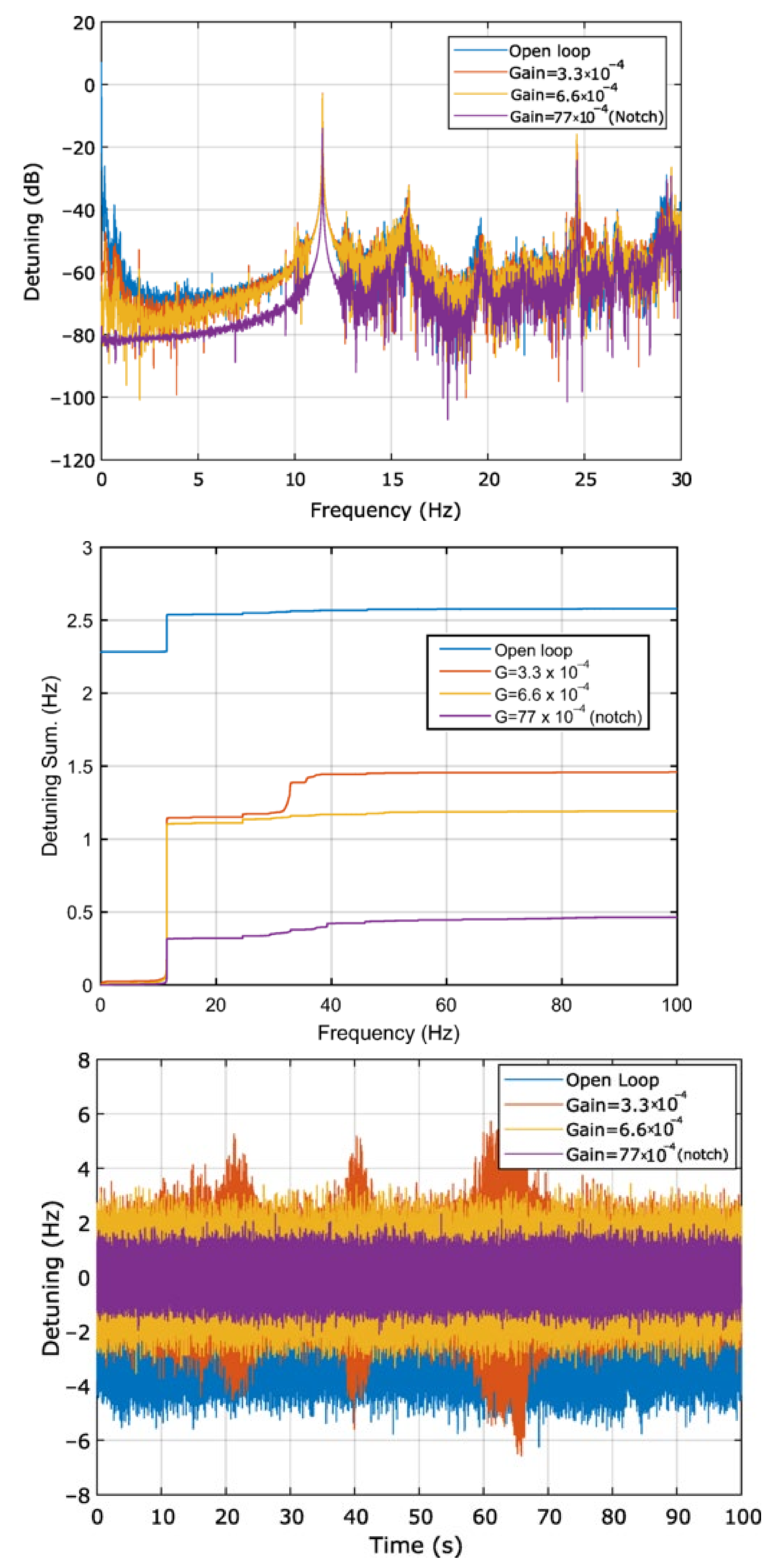


Control setup used in HZB to compensate for detuning of a TESLA cavity, (3).

RESULTS

Measured rms detuning for different gains of the controller ($\omega_e = 2000$ Hz and $\omega_c = 150$ Hz) in four different frequency ranges.

Gain	rms (Hz) 0–11.4 Hz	rms (Hz) 11.4 Hz	rms (Hz) 11.4–29 Hz	rms (Hz) 29–100 Hz
Open loop	2.2879	1.0950	0.2704	0.3781
3.3	0.1710	1.1317	0.2585	0.4908
6.6	0.1191	1.0931	0.2904	0.3555
77	0.0350	0.3137	0.1234	0.3188



Detuning of the TESLA cavity for different controller gains. A constant perturbation of 11.4 Hz is being fed into the system, (3): 1- Spectrum; 2- Integrated spectrum; 3- Time domain

CONCLUSION

- MADRC algorithm is a strong candidate for the control of low frequency stochastic microphonics. It is easy to implement and design and does not require too much prior information about the system to be controlled. In that sense, it shares many of the benefits and strengths of classical PID controllers but with better overall performance.
- It can be combined with feed-forward control systems to control constant frequency microphonics.
- Next step: implement it in a LLRF system

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