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MIMO approach for the longitudinal control of Advanced Virgo plus: interferometer and filter cavity

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Gravitational Wave (GW) detectors must use control loops to achieve the desired working point. Typically, these detectors have 4 or 5 main longitudinal Degrees of Freedom (DoFs) for which it is usually possible to extract suitable error signals by design. Therefore, they can be considered as diagonal systems allowing to close all the loops following a typical Single-Input Single-Output (SISO) control design approach. However, when the system is characterized by strong couplings among the different DoFs, this technique no longer holds and an alternative approach should be used: the Multiple-Input Multiple-Output (MIMO) system approach. Two main topics should be further investigated.
At first, a reliable system identification technique should be used to take into account the cross-couplings among the different DoFs.
Secondly, stability margins derived from SISO systems are often overoptimistic, becoming not valid for a MIMO closed loop system, introducing instabilities even for small variations of both gain and phase of the system. Therefore, it is necessary to study the robustness of the system in a different way.
In this work, we present the results obtained using a MIMO approach to describe the longitudinal controls of Advanced Virgo. At first, we describe a model of the control scheme for the 5 degrees of freedom of the interferometer. Then, we present a study made on the Frequency Dependent Squeezing (FDS) system: in particular, we describe the system identification technique and robustness study of a MIMO system composed by two inputs and two outputs: the main laser of the squeezed light source and the filter cavity.

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