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# Reset observers applied to MIMO systems☆

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ABSTRACT

A Reset observer (ReO) is a novel sort of observer consisting of an integrator, and a reset law that resets the output of the integrator depending on a predefined switching condition. For SISO systems, the switching condition is defined in such a manner that the ReO is reset when the output estimation error and the reset term have different sign. However, the way to define the reset condition to deal with MIMO systems has not been analyzed previously. As contributions, we provide a formulation to handle ReO for MIMO systems, and an algorithm to compute its $\mathcal{L}_2$ gain for performance purposes. Additionally, the effectiveness of our proposed MIMO ReO is analyzed by simulations.



## 1. Introduction

State observers for linear time invariant systems (LTIs) have been widely studied since 1970s (see, for instance, [1,2] and references therein). Those precursory works were characterized by having only a proportional feedback term in the estimation laws and were known as proportional observers (POs). After that, proportional integral observers (PIOs) were introduced to overcome the performance limitation of traditional proportional observers. Specifically, PIOs include an additional integral feedback loop, which increases robustness of the estimation process against disturbances, and modeling errors. They were initially introduced by Shafai and his co-workers for loop transfer recovery and robustness improvement in few publications (see [3,4] and the references therein). The adaptive version of this observer for linear systems was reported in [5,6], and generalized for certain class of nonlinear systems in [7].

Although PIOs outperform traditional POs, they are still affected by the inherent limitations of linear feedback control. That is, they cannot decrease the overshooting and settling time of the estimation process simultaneously. To overcome this drawback, a novel sort of observer named reset observer (ReO), was proposed in [8]. ReOs are observers consisting of an integrator and a reset law that resets the output of the integrator depending on a predefined switching condition. Similar to traditional proportional observers and PIOs, ReO can be regarded as a recursive algorithm for state estimation in dynamic systems, and therefore, it can play a key role in many applications such as monitoring, maintenance and fault tolerant control [9,10]. The main advantage of ReOs compared with traditional observers is that their estimation laws are no longer linear. Thus, the ReO overcome the inherent limitations of linear feedback laws. The introduction of the reset element, which is essentially nonlinear, in the estimation laws can improve the performance of the observer.

Reset elements for control purposes were firstly introduced by Clegg in 1958 [11], who proposed an integrator which was reset to zero when its input is zero. In 1974, Horowitz generalized that initial work substituting the Clegg integrator by a more general structure called the first order reset element (FORE) [12]. Nevertheless, the stability analysis of those early works were mainly based on simulations, and it would take two decades to find stability analysis demonstrations [13]. The main contribution of those works was a stability test applicable to reset control systems, called the $H_\beta$ condition. However, the $H_\beta$ condition is rather conservative, and it requires the plant dynamics to be stable [14]. Recently, reset elements based on the classical formulation have also been generalized to time-delay systems in [15,16], wherein the authors include the plant time delay in the stability analysis.

Additionally, some authors have been focused on improving the steady state performance of reset compensators. Since the state of the reset element is eventually reset, it does not have the characteristic of eliminating the steady state error in response to step disturbances by itself, thus, a steady state error is expected for all systems without an integrator. To overcome this drawback

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