

A Combined QFT/EEAS Design Technique for Uncertain Multivariable Plants

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Abstract - This paper presents a robust-adaptive control design for uncertain multivariable plants based on Quantitative Feedback Theory (QFT) and Externally Excited Adaptive Systems (EEAS). Design requirements are derived and formulated in terms of different cost functions. Also, a stochastic optimization technique is employed to optimally design the overall robust adaptive controller. This controller can handle large plant parameter uncertainties with lower control gains. Simulation results are provided to show the effectiveness and features of the proposed QFT/EEAS MIMO design methodology compared with the direct MIMO QFT design approach.

Index Terms – Robust Adaptive Control, QFT, EEAS, Stochastic optimization techniques.

I. INTRODUCTION

Quantitative Feedback Theory (QFT) is a powerful tool in the design of robust control systems for uncertain plants. The quantitative approach provides a design methodology which enables the designer to observe clearly the limitations and trade-offs in its design [1].

QFT design methodology for uncertain multivariable plants has provided a number of competing techniques. These can be generalized into two classes, being the non-sequential design methodologies [2] and sequential design methodologies [3, 4].

In solving an $m \times m$ multivariable design problem, the synthesis problem is converted into m equivalent single-loop MISO problems, with parameter uncertainties, external disturbances and performance tolerances are derived from the original problem, and the coupling effects between MISO subsystems are treated as disturbance inputs. These coupling effects need to be rejected in the QFT design of each subsystem. These can be designed by the SISO QFT design technique [5, 6].

The disturbance-rejection requirements will normally dominate the tracking-performance requirements, in the design of each subsystem [7]. On the other hand, in the case of plants with large parameter uncertainties, QFT design technique can lead to controllers with large bandwidth. These can result in high control gains that can cause actuator saturation and reduce the control-loop performance as well as leading to over design.

To overcome these deficiencies, QFT has been combined with other control techniques, such as the eigenstructure assignment [7] and the dynamics inversion technique [8]. Effort has also been put into designing non-diagonal controllers to reduce the gains of controllers [9-11].

Also, an adaptive QFT approach was proposed by [12] using Self Oscillating Adaptive Systems (SOAS). The resulted methodology was insensitive to large gain variations. This however causes limit cycles in the closed loop plant, which is not desirable in many practical applications.

In another approach Externally Excited Adaptive Systems (EEAS) are proposed to replace SOAS [13]. This will circumvent the need for the oscillation condition and improves the quality of closed loop performance.

This paper extends the robust adaptive design of controller using the QFT/EEAS approach [14] to multi-input multi-output (MIMO) systems. In all the quantitative designs, a time-consuming trial-and-error procedure is adapted and a successful compromise between various design requirements is very much dependent on the designer experience. In order to further improve the controller performance, the design steps involved are stated as design objectives and the problem is formulated as a constrained nonlinear optimization problem. The optimization problem is then solved using any of the standard random optimization techniques [15]. Genetic Algorithm is utilized here. Finally, to assess the feasibility and performance of the proposed design approach, simulation results are employed and comparison results with direct MIMO QFT are given which clearly indicate the advantages gained by the proposed design.

II. QUANTITATIVE FEEDBACK THEORY

QFT is a well established methodology for the design of two-degrees of freedom (2DOF) robust control systems [1]. The QFT method takes into account quantitative information on the plant's variability (uncertainty), the robust stability requirements, tracking-performance specifications, the expected disturbance amplitude and its attenuation requirements. The main steps involved in the QFT design can be summarized as: template generation, loop shaping and pre-filter design. These steps are