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Improved (non-)parametric identification of dynamic systems excited by periodic signals

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ABSTRACT

The steady state response of a system to a periodic input is still subject to noise transients. For lightly damped systems these noise transients can significantly increase the variance of the estimated frequency response function (FRF). This paper presents a method that suppresses the influence of the noise transients (leakage errors) in nonparametric FRF and noise (co-)variance estimates of dynamic systems excited by periodic signals. The method is based on a local polynomial approximation of the noise leakage errors on the FRF. Compared with the classical approaches, the proposed procedure is more robust and needs less measurement time (two signal periods are sufficient). The theory is supported by simulation and real measurement examples.

1. Introduction

Nonparametric frequency response function (FRF) estimates give a lot of insight in the dynamic behaviour of a system. It is measured by standard commercially available dynamic signal analysers and network analysers, and it is used in all kinds of engineering disciplines for analysis, modelling, design, detection, and prototyping [1–4]. Note that a good estimate of the variance of the FRF is as important as the FRF value itself: the noise variance is used to calculate uncertainty bounds on the FRF with a given confidence level [1–7], and is used as a nonparametric weighting in parametric identification of the system transfer function [8–14].

A first basic choice to be made when estimating the FRF concerns the nature of the excitation signal: arbitrary [1–3,15–22] or periodic [4,6,7,23–26]. Compared with arbitrary signals, periodic excitations have the following advantages [4]: (i) the magnitude of the DFT spectrum can be imposed exactly, (ii) suppression of the system transient (leakage) errors, (iii) the errors-in-variables problem (the input and output observations are noisy) is as easy as the output error problem (the input is known exactly), (iv) quantification of the noise and the nonlinear distortion, and (v) possible classification of the nonlinear distortions in even and odd contributions. The disadvantages of periodic signals are (i) the smaller frequency resolution, and (ii) the more complicated experimental set up (exact synchronisation between the generator and the acquisition units is needed). This paper handles the periodic case for single-input, single-output systems.

Although the steady state response of a dynamic system to a periodic input is not subject to system transient errors, it is still corrupted by the noise transients. For lightly damped systems these noise transients (leakage errors) can increase considerably the variance of the FRF estimate. In this paper we present a method for suppressing the noise transients

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