Improved (non-)parametric identification of dynamic systems excited by periodic signals—The multivariate case

R. Pintelon *, G. Vandersteen, J. Schoukens, Y. Rolain

Vrije Universiteit Brussel, Department of ELEC, Pleinlaan 2, 1050 Brussel, Belgium

ABSTRACT

Recently [1] a method has been developed to suppress nonparametrically the noise (and system) transients (leakage errors) in frequency response function and noise (co-)variance estimates of single-input, single-output systems excited by periodic signals. This paper extends the results of [1] to multiple-input, multiple-output systems where all inputs and outputs are disturbed by noise (i.e. an errors-in-variables framework). Two methods are presented: the first starts from multiple experiments with uncorrelated sets of inputs, and makes no assumption about the frequency response matrix (FRM); while the second only requires one single experiment, but assumes that the FRM can locally be approximated by a polynomial. Both methods estimate simultaneously the FRM, the noise level, and the level of the nonlinear distortions. For lightly damped systems, the proposed methods either significantly reduce the experiment duration or, for a given measurement time, significantly increase the frequency resolution of the FRM estimate. If the noise (and/or system) transients are the dominant error sources, then the proposed methods also significantly reduce the covariance matrix of the FRM estimates. The use of the nonparametric noise covariance estimates for parametric transfer function modelling is also discussed in detail.

1. Introduction

Frequency response functions give quickly insight in the dynamical behaviour of complex systems [2,3]. They are very useful for constructing and/or validating parametric transfer function model approximations of real life systems [4–6]. These parametric transfer function models are then used for virtual prototyping of new products, for physical interpretation and/or better understanding of the underlying physical phenomena, for prediction and/or control, for monitoring and fault detection ... .

Compared with single-input, single-output systems, the frequency response function (FRF) estimate of a multivariable system is much more involved. Indeed, since the frequency response matrix (FRM) is typically obtained via cross-correlation techniques [2,3,7], the input signals should be minimally correlated. Otherwise, the input power spectrum matrix can be almost singular, which results in unreliable FRM estimates. On the other hand, the FRM of a highly interactive process can be ill-conditioned by the nature of the system itself. Accurate identification of the low gain directions of the FRM then requires high amplitude correlated inputs [8,9], and this is in conflict with the previous requirement for uncorrelated excitations. This challenging problem will not be handled here.