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Review

Robust synchronization of different coupled oscillators: Application to antenna arrays

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Abstract

This paper deals with the synchronization of a chain of nonlinear and uncertain models of nonidentical oscillators. Using Lyapunov's theory of stability, a dynamical controller guaranteeing the synchronization of the oscillators is determined. The problem of synchronization is transformed into a problem of asymptotic stabilization for a nonlinear system and then is formulated as a system of linear matrix inequalities where the parameter variations of the two oscillators and their differences are modeled by polytopic matrices. The theoretical result is successfully applied to an array of transistor-based oscillators used in "smart antenna" systems.

Keywords: LMI; Robust control; Control applications; Antenna arrays

Contents

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1. Introduction

The demand of mobile communication services is continuously growing. Moreover, it is estimated that this trend will be maintained in the coming years. This continuous development has stimulated the research of new hardware and software solutions in order to increase the volume of exchanged data and to enhance the management of the emitted or received electromagnetic field.

Smart antennas or antenna arrays are a part of communication systems that improve their global performances. Antenna arrays increase the spectral efficiency and reduce the multi path fading, bit error rate (BER), the co-channel interferences (CCI) and the system complexity [1]. This is possible by electronically adjusting the radiation pattern of the antenna array in order to provide a large gain for the desired signals and a small gain for interference signals.

One of the challenges to control such devices is to generate signals with the same frequency but different phases and amplitudes. The present paper proposes some variation of a technique inspired from radar applications: the generation of synchronized and phase shifted signals using arrays of coupled nonlinear oscillators.

The work that has been done in the field of dynamics of coupled nonlinear systems using the frequency approach [2–8] shows that they offer easy methods of phase control among array elements. Hence, beam scanning capabilities are provided. However, it implies problems of stabilization. The present paper treats the synchronization of a system made by two oscillators with a unidirectional coupling. The problem of synchronization is transformed into a problem of stabilization for a nonlinear system. The chosen strategy consists in finding an output feedback dynamic controller using Lyapunov control functions.

The problem of computing stabilizing dynamic output feedbacks with constrained order on LTI (linear time-invariant) systems in terms of matrix inequalities is difficult to solve. In fact, a solution can be determined by a set of bilinear matrix inequalities (BMI). There are two techniques: the iterative algorithms and the elimination of variable products by using the matrix separation lemma. The second method has been chosen. In certain cases, this method transforms the initial BMI into a set of LMI-s which can be numerically solved [9–14].

The variation of the parameters is taken into account by considering the state matrix as a polytopic one. The presented technique involves the use of Lyapunov functions that depend on the polytopic structure of the uncertainty in order to reduce the conservatism of the method. This work refers to the results of [15]. The reader is invited to see [16–19] where tractable results relevant to parameter-dependent Lyapunov functions are proposed. Once the stability of the vertices, defined for the polytope is demonstrated, the stability and hence the synchronization of the two oscillators is assured for all systems inside the polytope.

It was proved in [16,20] that the polytopic structure reduces conservatism. The improvement has been numerically verified in [21]. In the discrete-time case, a less