Commun Nonlinear Sci Numer Simulat 14 (2009) 1590–1597

Contents lists available at ScienceDirect

Commun Nonlinear Sci Numer Simulat

journal homepage: www.elsevier.com/locate/cnsns

Synchronization of Colpitts oscillators with different orders

J.Y. Effa [a,*], B.Z. Essimbi [a], J. Mucho Ngundam [b]

[a] *Département de Physique, Faculté des Sciences, Université de Yaoundé 1, B.P. 8251 Yaoundé, Cameroun*

[b] *Département des Génies Electrique et Télécommunication, ENSP, Université de Yaoundé 1, B.P. 8390 Yaoundé, Cameroun*

ARTICLE INFO

Article history:
Received 12 February 2008
Received in revised form 25 March 2008
Accepted 25 March 2008
Available online 23 May 2008

PACS:
05.45.Xt
05.45.Pq

Keywords:
Microwave improved and standard chaotic Colpitts oscillator
Chaotic systems with different orders
Synchronization
Computer experiments

ABSTRACT

In this paper, we consider chaos synchronization between chaotic Colpitts oscillators with different orders, consisting of standard and improved version of Colpitts oscillators. Firstly, the normalized state equation of the improved version of the Colpitts oscillator designed to operate in the ultrahigh frequency range are presented. It is found that this version is described by fourth-order nonlinear differential equations. The equations of motion are solved numerically using the Runge–Kutta algorithm and simulations demonstrate chaos in the microwave frequencies range. Secondly, the problem of synchronization dynamics of third and fourth orders systems in the chaotic states is also investigated, and a controller is proposed based on stability theory by constructing the Lyapunov function, to ensure synchronization between both oscillators. Computer experiments demonstrate the effectiveness and feasibility of the proposed technique for these oscillators.

1. Introduction

In the past two decades, it has been shown that the standard Colpitts oscillator, with special settings of the circuit parameters can exhibit chaotic behaviour. This circuit was investigated at the kHz frequencies [1], high (3–300 MHz) frequencies [2] and ultrahigh (300–1000 MHz) frequencies [3] both numerically and experimentally. Later, an alternative to this standard version of Colpitts oscillator has been suggested [4,5] in order to exhibit higher fundamental frequencies in a chaotic regime: a two-stage and an improved Colpitts oscillators.

The study of chaotic oscillations to information technologies [6] is under intensive investigation. In this frame, there is a great interest behind the study of chaotic oscillator operating at high MHz frequencies, due to it potential application in future communication systems [7] and in radar systems [8]. In order to recover the information, the chaotic generator (drive system) in the transmitter must be synchronized with the chaotic generator (response system) in the receiver. Therefore, chaos synchronization refers to a process wherein two (or many) chaotic systems (either identical or non-identical) adjust a given property of their motion to a common behaviour due to coupling or forcing. To synchronize Colpitts oscillators, either nonlinear Pecora–Caroll method [9,10] or linear coupling technique [7,11,12], adaptive synchronization [13], active control synchronization [14], linear feedback control method [15], observer-based synchronization [16] and so on have been employed. Here, the two chaotic Colpitts oscillators to synchronize may be identical [7,8,10–12,14–16] or non-identical with different parameters [12,13]. However, it is difficult to find identical chaotic systems in reality, especially there are mismatches in parameters of the systems. Recently, a lot of effort has been devoted for example to synchronize a class of chaotic systems in the presence of system's disturbances and unknown parameters [17]. And, the proposed adaptive observer-based

* Corresponding author.
E-mail address: effa_jo@yahoo.fr (J.Y. Effa).

1007-5704/$ - see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.cnsns.2008.03.019

synchronization operated satisfactorily in the communication application. Thus, it is important and interesting to investigate synchronization behaviour between non-identical Colpitts oscillators. Although the method of the synchronization of two different chaotic systems is far from being straightforward, in this work, we address the problem of chaos synchronization between two non-identical Colpitts chaotic oscillators with different orders designed to operate in the ultrahigh frequency range. This is done numerically by means of integration of simplified (piecewise-linear) differential equations. Following Ref. [18], we propose a controller based on stability theory by constructing the Lyapunov function, to ensure chaos synchronization of non-identical standard and improved version of Colpitts oscillators.

The paper is organized as follows. In Section 2, the circuit model for the standard and improved chaotic Colpitts oscillators are introduced and normalized state equations are presented while their chaotic behaviour is confirmed. Section 3 deals with the synchronization state of chaotic oscillators with different orders. In Section 4, computer experiments are also undertaken to validate this approach. Finally, Section 5 concludes the paper.

2. Circuits and basic equations of oscillators

In this section we briefly introduce the circuits under investigation and give their corresponding state space equations using a piece-wise linear approximation of nonlinear *I–V* characteristic of the bipolar junction transistor (BJT). We also studied the continuous autonomous systems by depicting their typical phase portrait.

2.1. The improved Colpitts oscillator

As described in Ref. [5], we consider the configuration of the improved Colpitts oscillator which is schematically represented in Fig. 1. It contains a BJT as the gain element and a resonant network consisting of an inductor and a pair of capacitors. The difference from the standard circuit diagram of the usual Colpitts oscillator is that the inductor L is moved from the collector circuit to the base where it is in series with resistor R_b. Thus this model cannot be attributed to any common-node configuration like a standard version. The basic mechanism behind this configuration is to diminish negative influence of the capacitor C_{CB} (zero-bias collector-base capacitance) at ultrahigh frequencies. Indeed, capacitor C_{CB} in standard version of Colpitts oscillator grounds the collector node and acts as a parasitic element destroying chaotic oscillations [19]. In this novel version, L and R_b screen C_{CB} from the ground and diminish its negative influence. In Ref. [5], improved chaotic Colpitts oscillator was experimentally simulated by using the microwave transistor BFG520 and chaos was predicted in the microwave frequencies range. However, basic equations of improved version of Colpitts oscillator have not been reported.

Now, let us consider the following state equations for the improved Colpitts oscillator in Fig. 1. given by

$$\begin{cases} RC_1\frac{\mathrm{d}V_{C1}}{\mathrm{d}t} = V_0 - V_{C1} - V_{C2} + RI_L - RI_B - RI_C, \\ RC_2\frac{\mathrm{d}V_{C2}}{\mathrm{d}t} = V_0 - V_{C1} - V_{C2} - RI_0 + RI_L, \\ L\frac{\mathrm{d}I_L}{\mathrm{d}t} = -R_bI_L - V_{BE} - V_{C2}, \\ C_{\mathrm{CB}}\frac{\mathrm{d}V_{\mathrm{BC}}}{\mathrm{d}t} = I_L - I_B. \end{cases} \tag{1}$$

This system describes a set of four nonlinear differential equations as

$$\begin{cases} RC_1\frac{\mathrm{d}V_{C1}}{\mathrm{d}t} = V_0 - V_{C1} - V_{C2} + RI_L - R(\beta+1)I_B, \\ RC_2\frac{\mathrm{d}V_{C2}}{\mathrm{d}t} = V_0 - V_{C1} - V_{C2} - RI_0 + RI_L, \\ L\frac{\mathrm{d}I_L}{\mathrm{d}t} = -R_bI_L - V_{\mathrm{BE}} - V_{C2}, \\ RC_1\frac{\mathrm{d}V_{\mathrm{BE}}}{\mathrm{d}t} = V_0 - V_{C1} - V_{C2} + R\left(1+\frac{C_1}{C_{\mathrm{CB}}}\right)I_L - R\left(1+\frac{C_1}{C_{\mathrm{CB}}}+\beta\right)I_B, \end{cases} \tag{2}$$

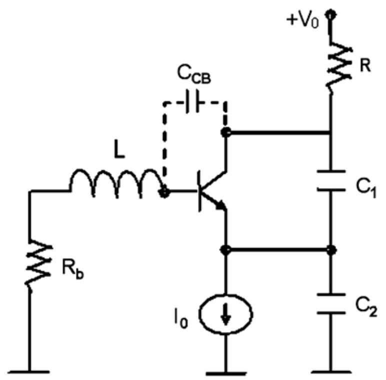

Fig. 1. The circuit diagram of improved chaotic Colpitts oscillator.