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Full Synchronization of 2×2 Optocouplers Network Using LEDs

Kejeen M. Ibrahim and Raied K. Jamal

[1]*Department of physics, college of science, University of Baghdad, Baghdad, Iraq.*

Address For Correspondence:
Kejeen M. Ibrahim, Department of physics, college of science, University of Baghdad, Baghdad, Iraq.

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ABSTRACT

The synchronization of a complex network with optoelectronic feedback has been introduced theoretically, with use of 2×2 oscillators network; each oscillator considered is an optocoupler (LED coupled with photo-detector). Fixing the bias current (δ) and increasing the feedback strength (Ɛ) of each oscillator, the dynamical sequence like chaotic and periodic mixed mode oscillations has been observed. Synchronization of unidirectionally coupled of light emitting diodes network has been featured when coupling strength equal to 1.7×10^{-4}. The transition between non-synchronization and synchronization states by means of the spatio-temporal distribution has been investigated.

INTRODUCTION

Chaos synchronization is a universal phenomenon that can occur when two, or more, dissipative chaotic systems are coupled (E. Scholl 2008, Inés Pérez Mariño 1999). Chaos synchronization has been broadly studied for various systems from different aspects(Chen and Liu2004),and it has many potential applications in laser physics, secure communication, chemical reactor, biomedical and so on (G. Cai& Z. Tan 2007).Optical communications using chaotic transmitters and receivers offers the potential of an enormous usable bandwidth for high bit rate data communication or utilization of the available bandwidth by many users (Henry D. I. Abarbanel 2001).The systems might be identical or different, the coupling might be unidirectional (master–slave or drive–response coupling) or bi-directional (mutual coupling) and the driving force might be deterministic or stochastic (G. Giuliani 2005). In secure communications, a message can be secreted in the output of a chaotic system during transmission and can be recovered by using a copy of the original system, synchronized to the first (Sora F. Abdalah 2011). In optical chaos communications, the chaotic waveform is usually generated by semiconductor lasers subjected to either all optical or electro-optical feedback (V. Z. Tronciu 2010). The synchronization in a network of coupled light emitting diodes (LED) in the presence of AC-filtered nonlinear opto-electronic feedback has been investigated theoretically (M.Ciszak).A GaAs light-emitting diode (LED) with ac-coupled nonlinear optoelectronic feedback has been shown to exhibit complex dynamics including mixed mode oscillations and chaos (Bei Liu 2015). Typical time traces consist of large pulses separated by irregular time intervals in which the system displays small-amplitude chaotic oscillations (Sora F. Abdalah 2011).A chaotic oscillator based on incoherent light source (LEDs) with AC coupling reported by Abdalah *et al*. (S. F. Abdalah 2012, S. F. Abdalah 2011 Can be utilized to establish four elements network in MMOs regime (S. Abdalah2013). The goal of this paper is to achieve complete synchronization among four LEDs as a network. In each network, LEDs are coupled uni-directionally.

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LEDs system model:

In Figure 1 shows the configuration includes four oscillators; each oscillator considered is an optocoupler (LED coupled with photo-detector) as shown in Figure2 with AC coupled nonlinear optoelectronic feedback. These oscillators are coupled through the detector photocurrent to form network.

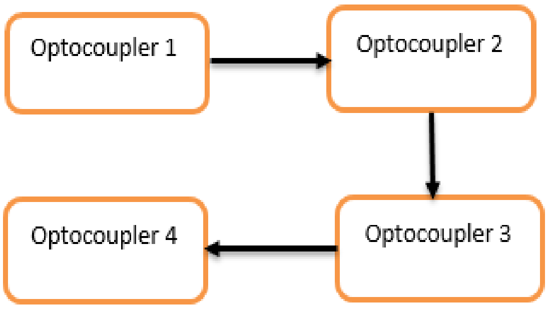

Fig. 1: configuration of the nearest neighbor closed loop.

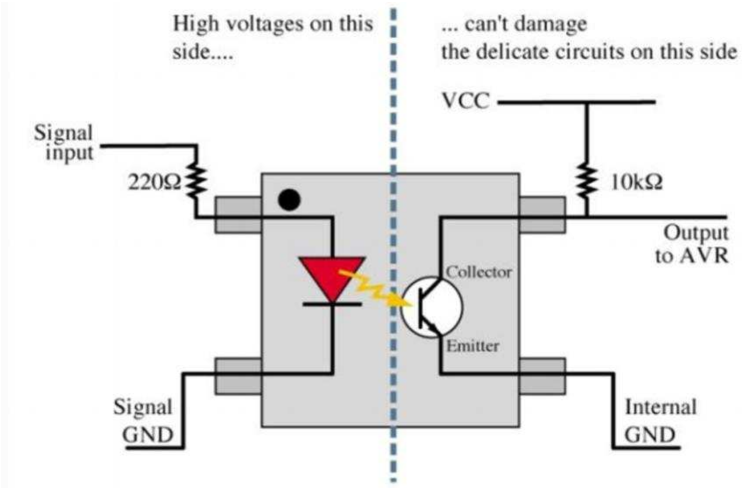

Fig. 2: optocoupler (LED coupled with photo-detector)

In one dimension, the unidirectionally coupled systems are defined as following (S. F. Abdalah 2011):

$$\dot{x}_i = f(x_i) + K(x_{i-1} - x_i)$$

For numerical and analytical purpose, the N-LED system is written in dimensionless form (i.e. Al-Naimee model):

$$\dot{x}_i = x_i(y_i - 1) + \gamma y_i$$

$$\dot{y}_i = \gamma(\delta - y_i + \frac{a(z_i + x_i)}{(1 + s(z_i + x_i))} - x_i y_i)$$

$$\dot{z}_i = -\varepsilon(z_i + x_i) + \sum_{j=1}^{N} g_{ij} z_i$$

where i= 1,2, N, x-the photon density, y - carrier density, z - high-pass filtered feedback current, where δ is the solitary laser threshold current, γ is the ratio between photon and carrier lifetimes, the term $a\frac{(x+z)}{(1+s(z+x))}$ represents feedback amplifier function, where a is an amplifier gain and s is saturation coefficient, g_{ij} is the coupling strength, and The system parameters are set as γ=0.01, a=1, s=0.2 and δ=2.75, and N =4.

Synchronization numerical results:

Here we present results on synchronization in a network of four light emitting diode (LED) in the presence of AC-filtered nonlinear opto-electronic feedback. Each LED can undergo a variety of dynamical behaviors like chaotic and periodic mixed mode oscillations. Indeed, a variety of natural system showing this behavior Figure 3, like neural cells, cardiac tissues and chemical reactions. This system sometimes called (slow-fast systems).

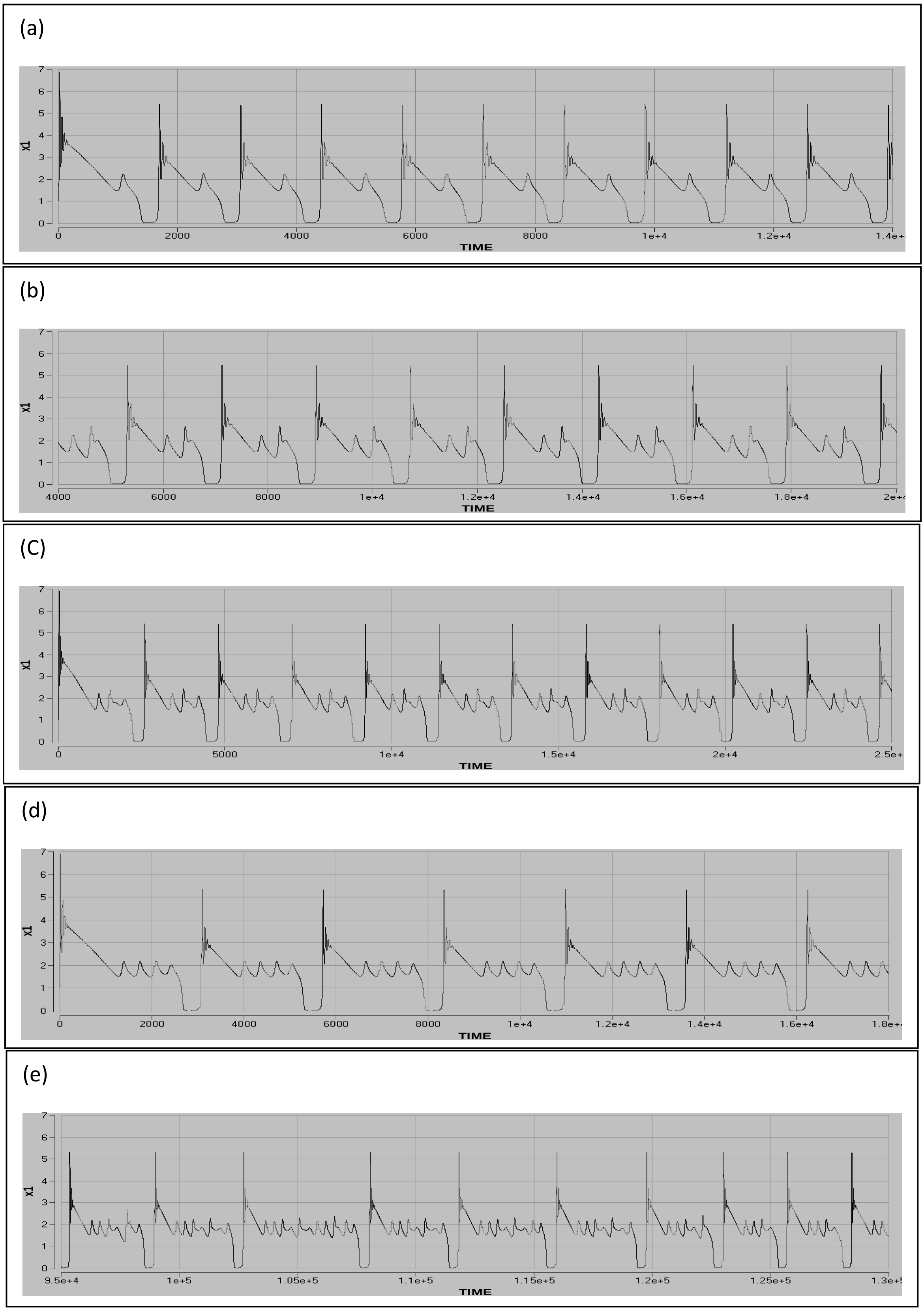

Fig. 3: The numerical time series at feedback strength Ɛ, (a) 0.00122, (b) 0.0012 (c) 0.00108, (d) 0.00092 (e) 0.00091

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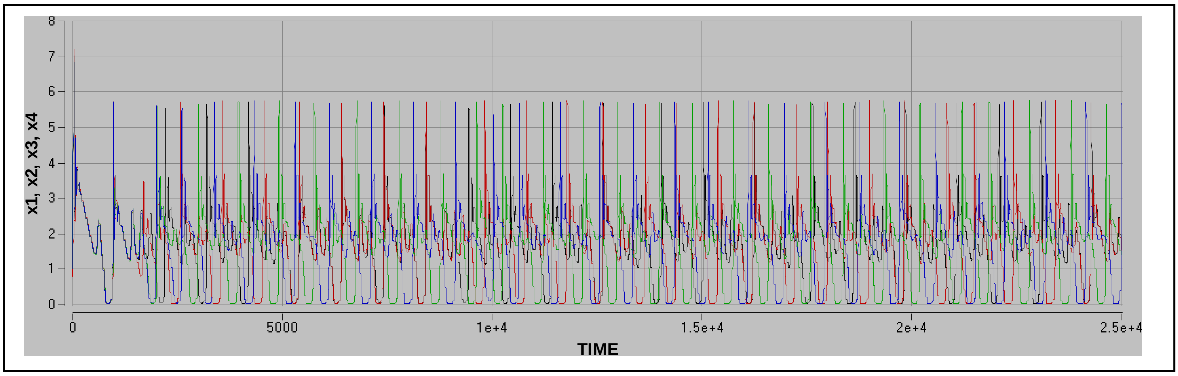
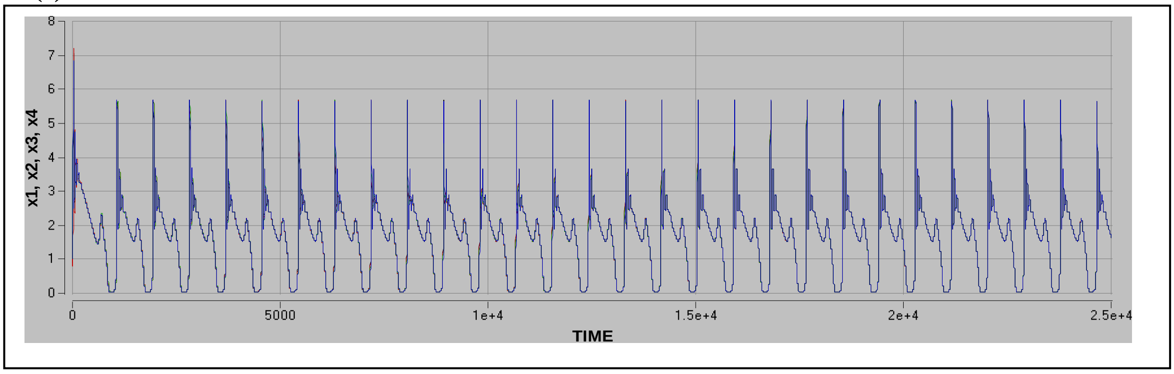
Four LEDs have been coupled, in this case the feedback strength and the bias used to feed all of the oscillators. Fixed the bias current (δ) and increasing the feedback strength (Ɛ) of each oscillator, the dynamical sequence has been observed. The corresponding dynamical sequence of the above procedure is illustrated in Figure 3(a-d) that contain the time series of different values of feedback strength. The chaotic dynamics appears clearly in figure 3(e), at feedback strength equals to 9.1×10^-4. By increasing the feedback strength of each oscillator, we observed the dynamical sequence shown in Figure 4(a), when the oscillators are running independently (coupling strength g is zero). When the coupling strength g increased (g=7.9˟10^-4) the spiking come at the same time sequences Figure 4(b), and full synchronization of periodic mixed-mode oscillations has been obtained.



(a)



(b)

Fig. 4: Numerical time series of the oscillators outputs for (a) non synchronization and (b) full synchronization network.

To describe quantitatively the abrupt change the degree of order in the system characterized by means of spatiotemporal distribution. The space-time representation of the LEDs intensities and report the horizontal black bars the occurrence of the largest spikes according to the previously described procedure as in Figure 4. When the coupling strength g is zero the oscillators are running independently (non-synchronization) when the spikes possess the distribution of different times Figure 5(a), for g = 7.9˟10^-4 we observe appearance of synchronization, this mean the perturbation from the first oscillator in the network propagation the whole array reaching to the last oscillator, and all the peaks have an equal distribution of the times as shown in Figure 5(b).

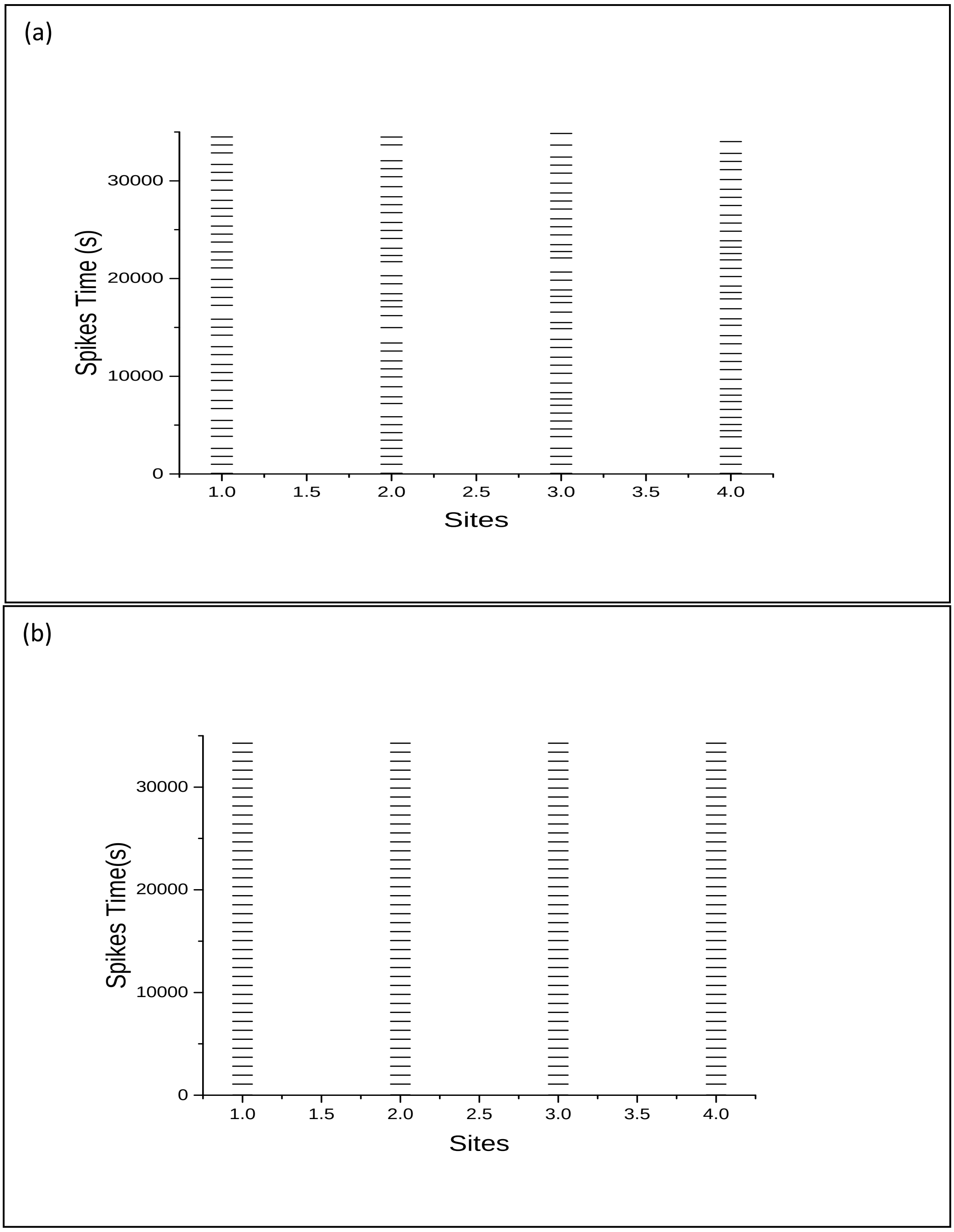


Fig. 5: Spatio-Temporal distributions for (a) non-synchronization, (b) synchronization conditions

Conclusions:

The unidirectional synchronization of LEDs network has been presented theoretically. The synchronized state has been analyzed in terms of the time series and the spectra of the oscillator outputs, the time series of all of the network units partly follow each other was found. Spatio-Temporal distributions of the response times, measured between all interacting units. A miniaturized LED network containing many nodes imitating a neural network has been created and it is an important advance which can contribute to technological applications.

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