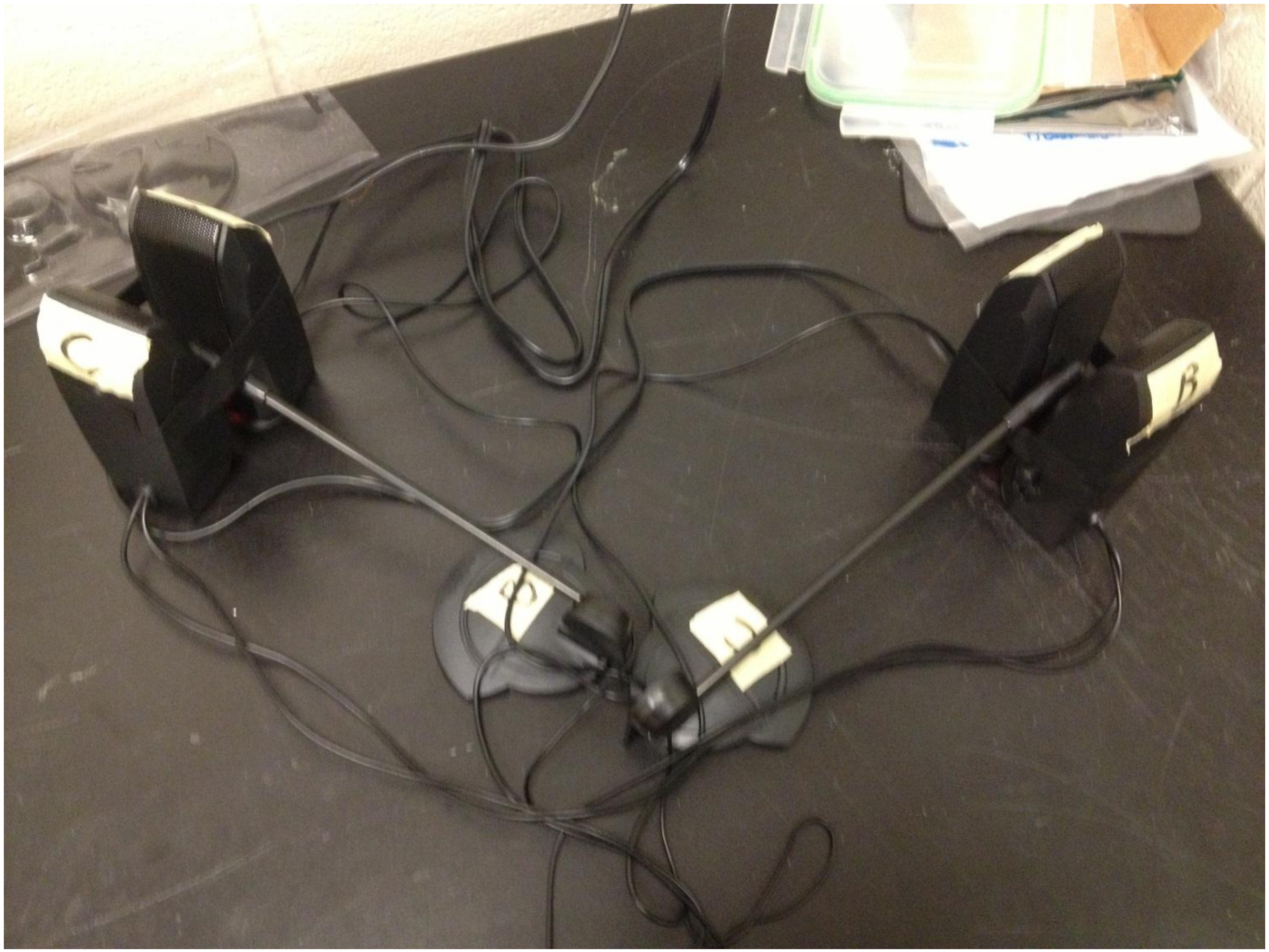
Acoustic Synchrony

Justin Blythe
Yuxuan Jiang

Introduction

- Do crickets synchronize their chirps with neighboring crickets?
- A field study by Thomas J. Walker in 1969 found that they do, but under certain conditions.
- Walker took recordings of actual crickets, and played them back them to discover if a neighboring cricket would alter it’s chirp rhythm to synchronize.
- He found that that neighboring crickets would synchronize their chirp, but not the number of pulses it chirps.
- We set out to reproduce these results with a simple microphone and speaking coupling.

Our Two Crickets



Experimental Setup

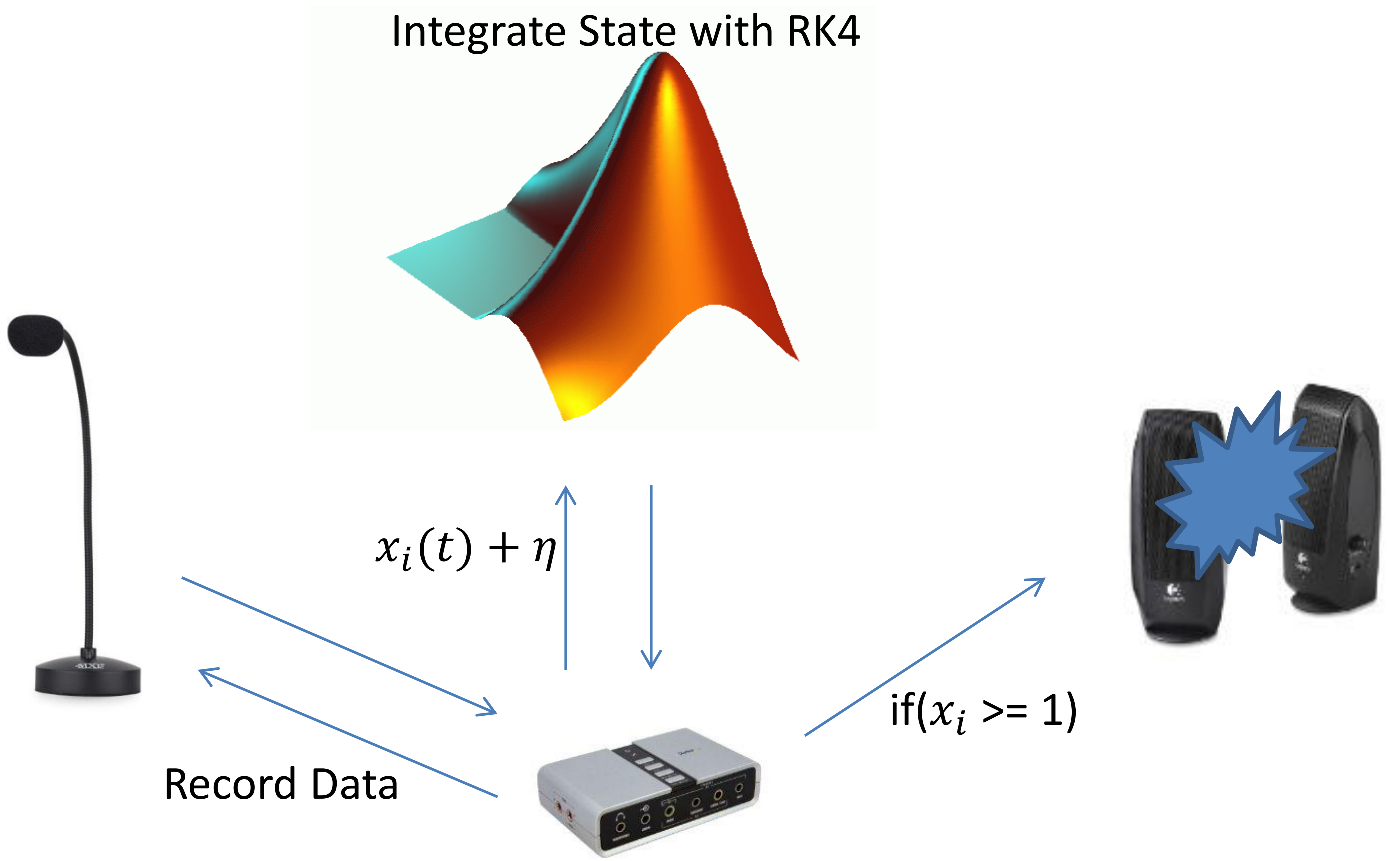
Supplies for each cricket:

1. USB soundcard
2. Microphone
3. Speaker
4. MATLAB window

Experimental Setup

- We wrote a MATLAB function that was able to communicate with the soundcard that had a speaker and microphone attached to it.
- Using a state variable, discussed previously, we would integrate the equation using a Runge-Kutta fourth order ODE solver (probably a bit much but I already had one).
- The microphone would record short instances in time and if it recorded anything louder than a certain threshold variable, which we set, it would add η to the current state variable.
- Once the state variable reached one, it played a chirp. While playing a would could listen to it’s neighbor and we toggled the ability for listening to itself.

Experimental Setup



A Model for Pulse-Coupled Oscillators

Initially, we started with a model by Steven Strogatz. Given by,

$$\frac{\partial x_i}{\partial t} = \omega_0 - \gamma x_i$$

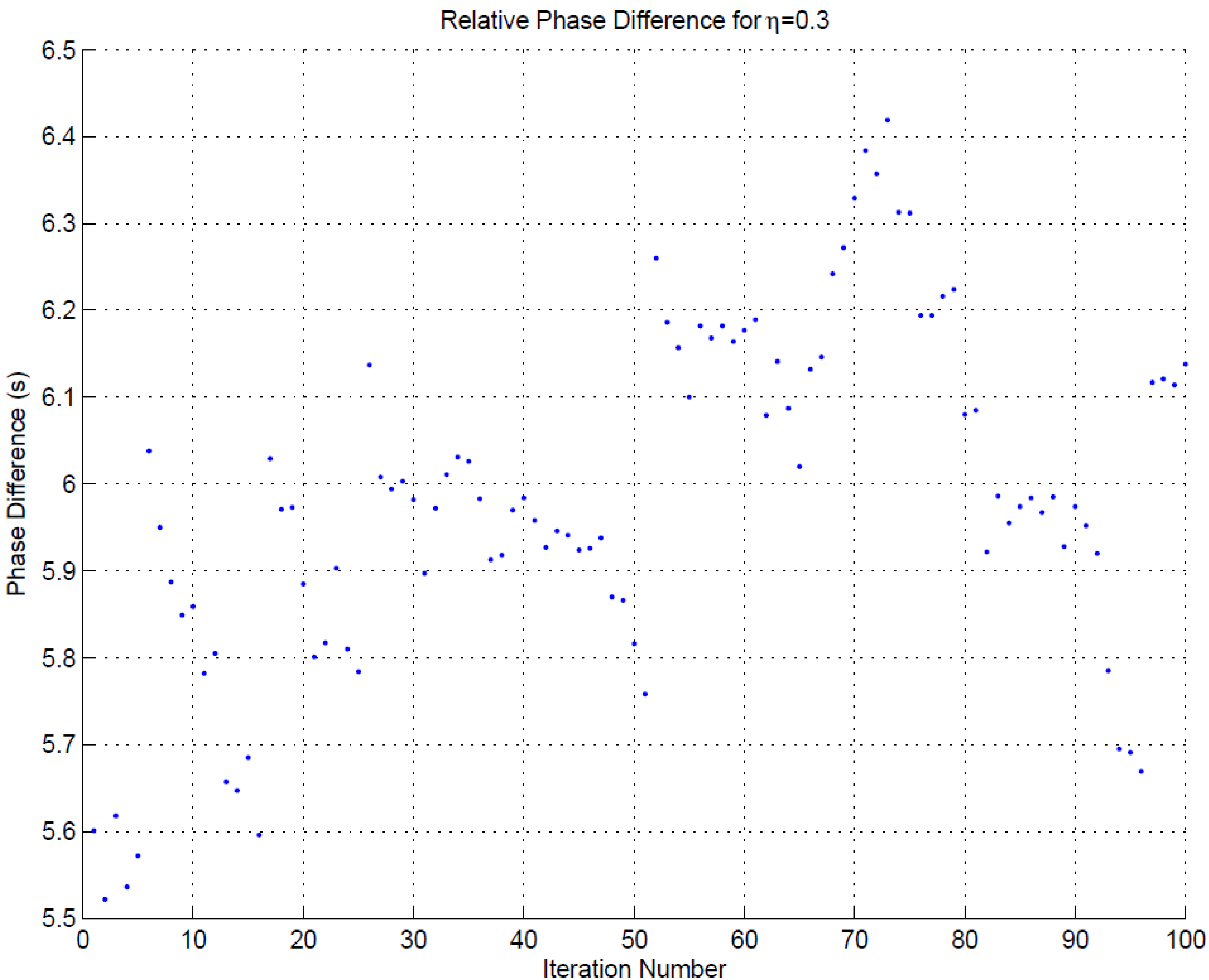
where the state $x_i \in [0,1]$, ω_0 is the natural frequency, and γ is a dissipative term. The correction condition for phase shift is

$$x_i = 1 \Rightarrow x_j(t^+) = x_j(t) + \eta$$

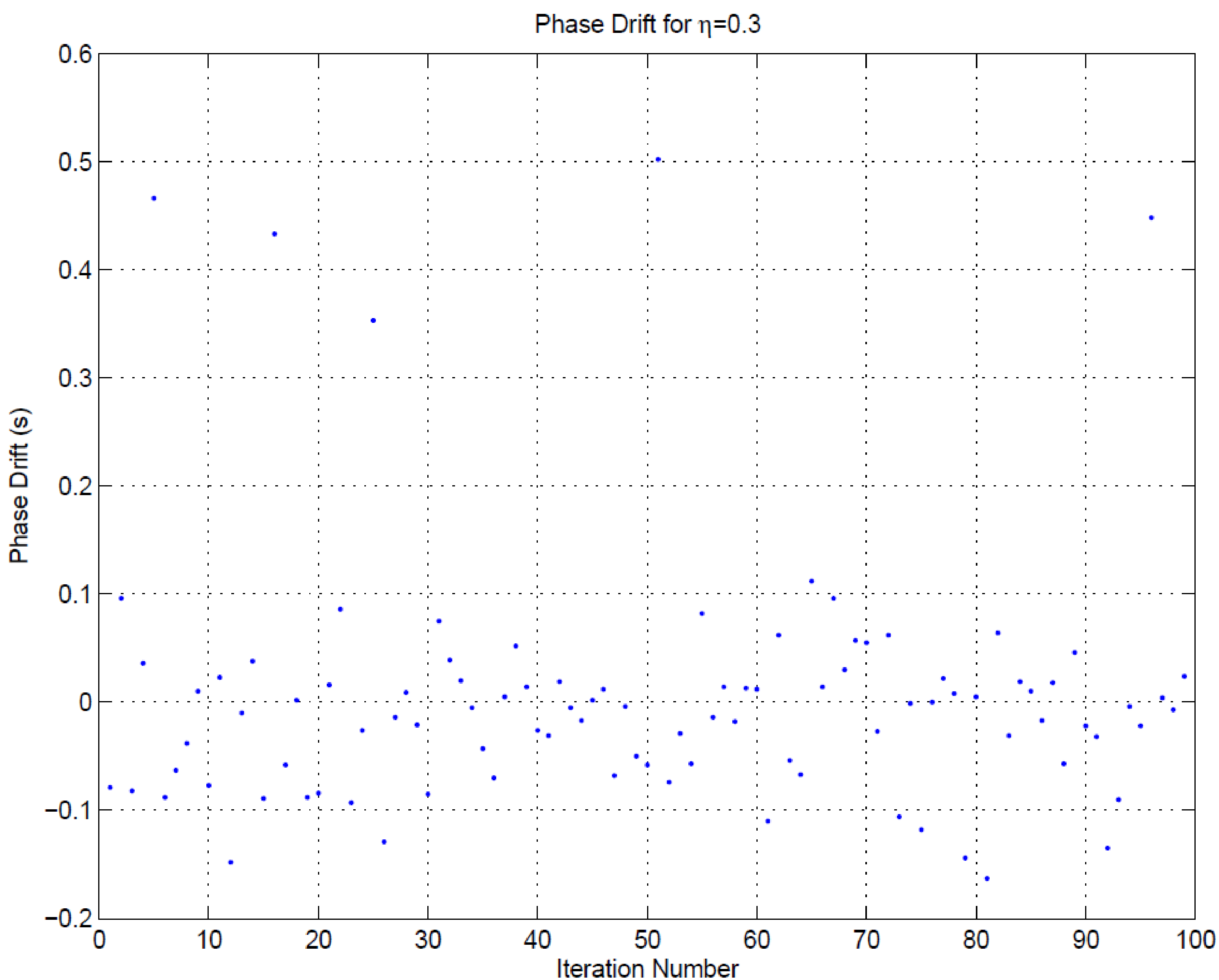
where η is the coupling strength of the cricket and its neighbor.

Strogatz Model

- $\gamma = 0.05$
- $\eta = 0.3$
- $\omega_{0L} = 12.01$
- $\omega_{0F} = 11.98$



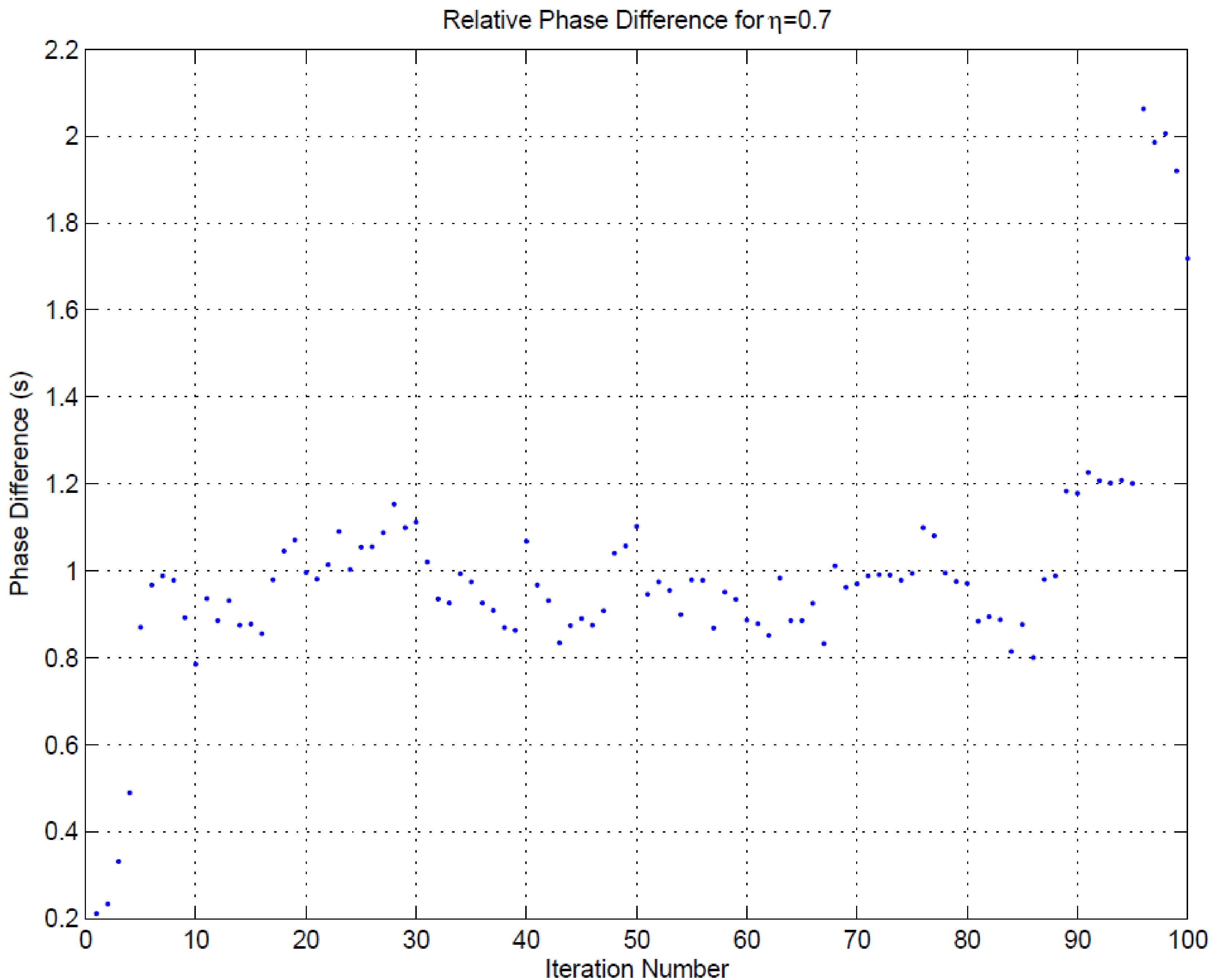
Relative Phase Difference for η=0.3
Phase Difference (s)
Iteration Number
6.5
6.4
6.3
6.2
6.1
6
5.9
5.8
5.7
5.6
5.5
0
10
20
30
40
50
60
70
80
90
100



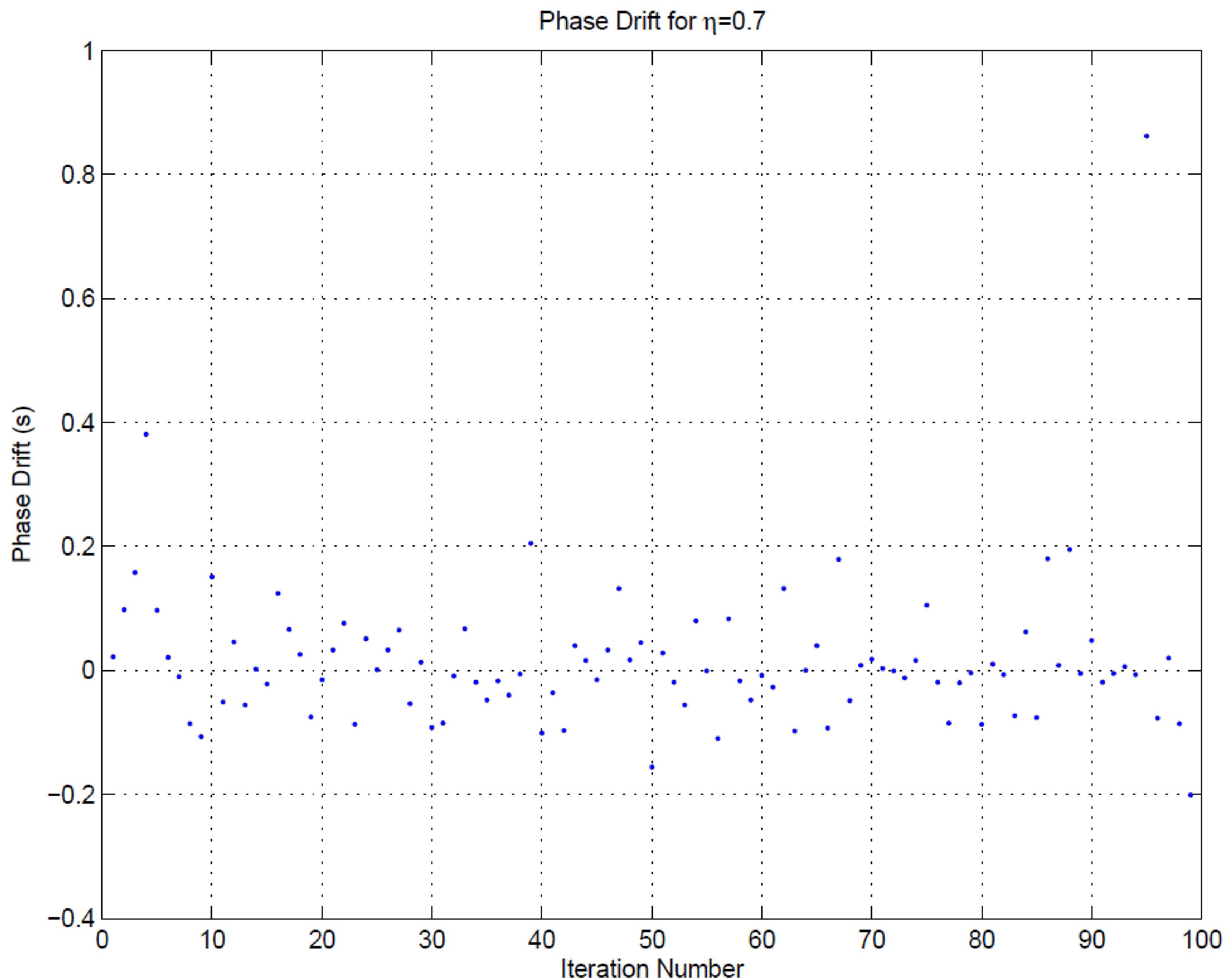
Phase Drift for η=0.3
Phase Drift (s)
Iteration Number
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
0
10
20
30
40
50
60
70
80
90
100

Strogatz Model

- $\gamma = 0.05$
- $\eta = 0.7$
- $\omega_{0L} = 12.01$
- $\omega_{0F} = 11.98$



Relative Phase Difference for η=0.7
Phase Difference (s)
Iteration Number
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
10
20
30
40
50
60
70
80
90
100



Phase Drift for η=0.7
Phase Drift (s)
Iteration Number
1
0.8
0.6
0.4
0.2
0
−0.2
−0.4
0
10
20
30
40
50
60
70
80
90
100

A Modified Model

To simplify the model we neglected the dissipative term.

$$\frac{\partial x_i}{\partial t} = \omega_0 + \zeta(t)$$

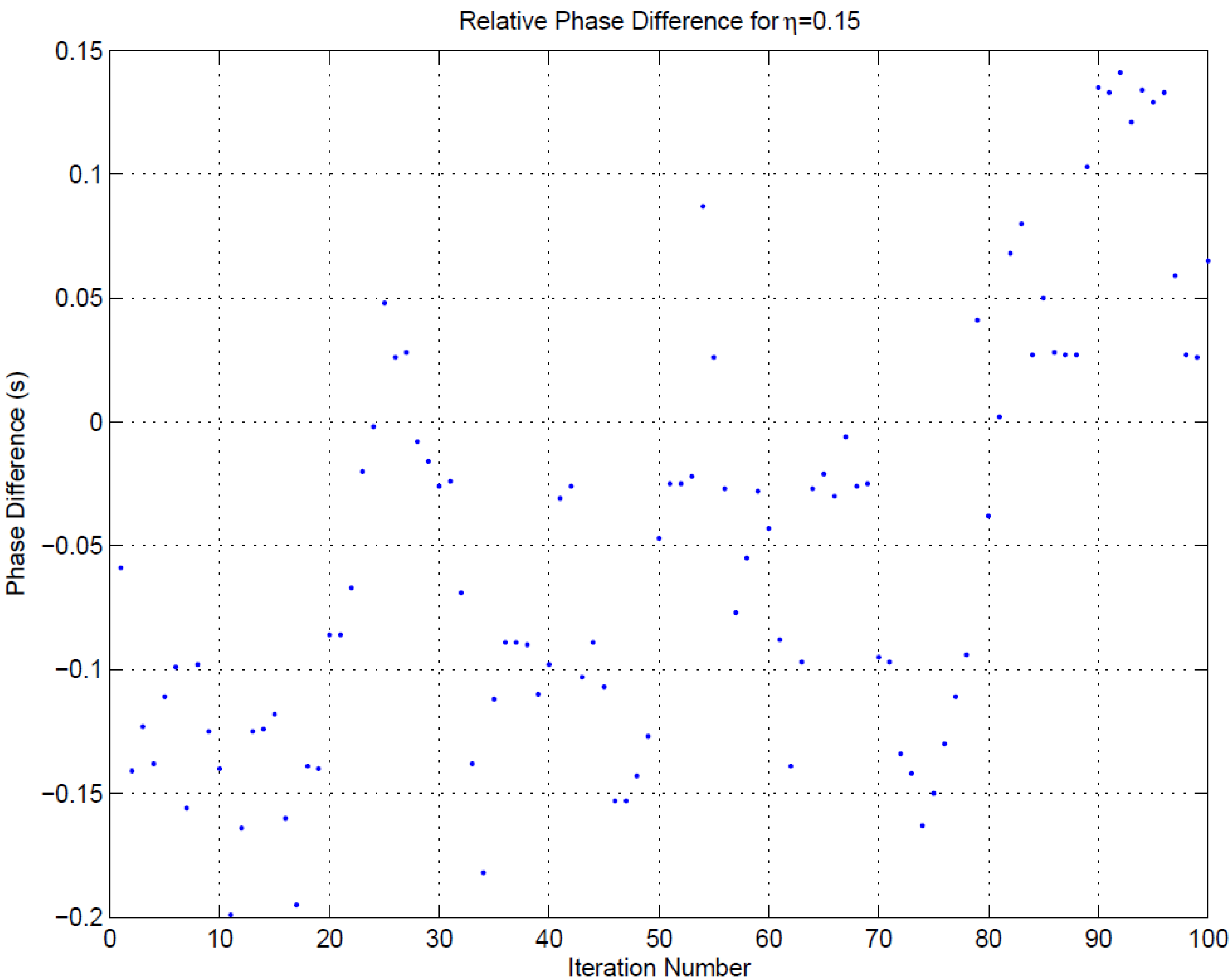
where $\zeta(t)$ is the external noise, which we took to be the mean of the recorded data.

Plots of Data

with parameter values:

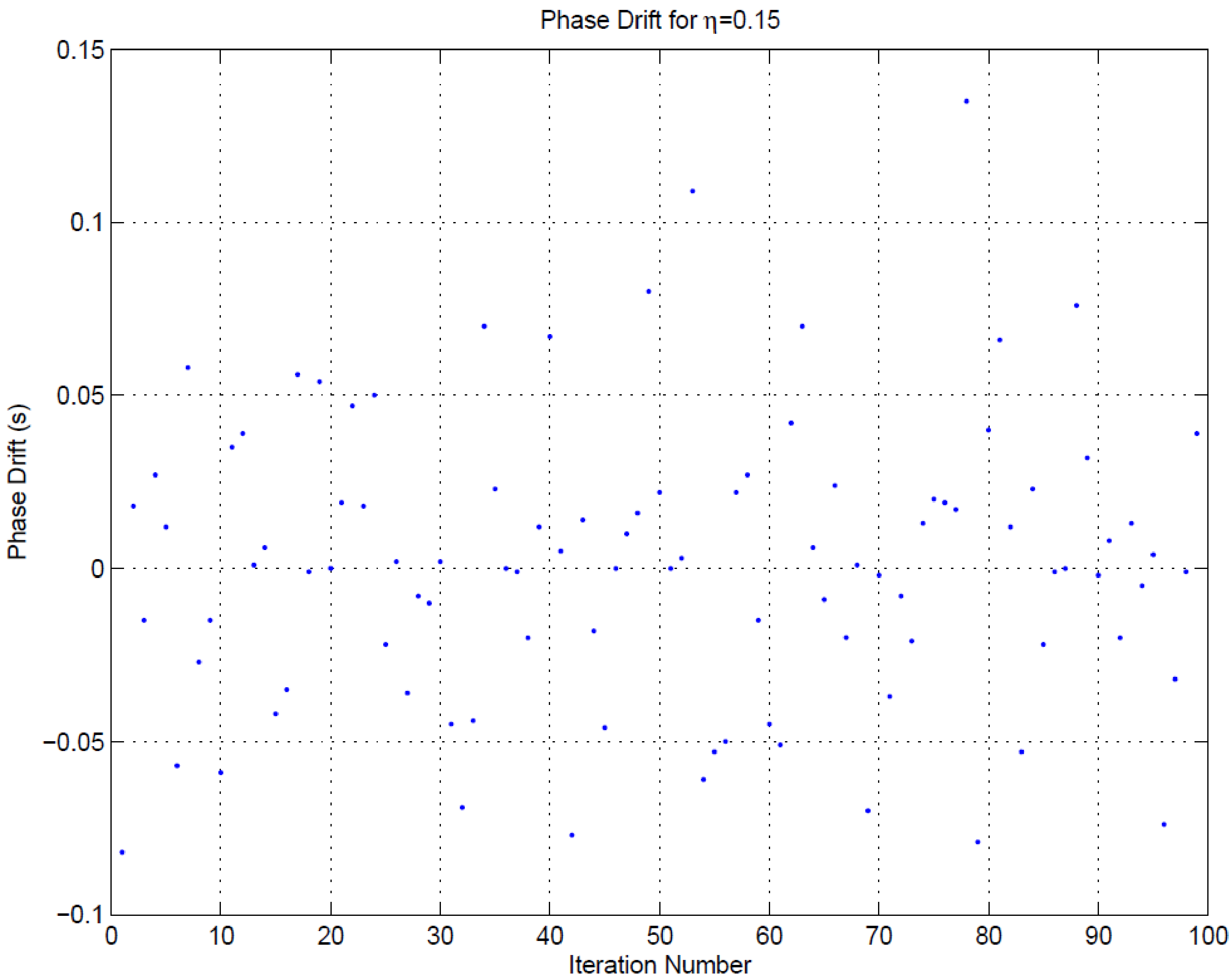
$$\omega_{0L} = 12.01$$
$$\omega_{0F} = 11.98$$
$$\gamma = 0$$

Synchrony



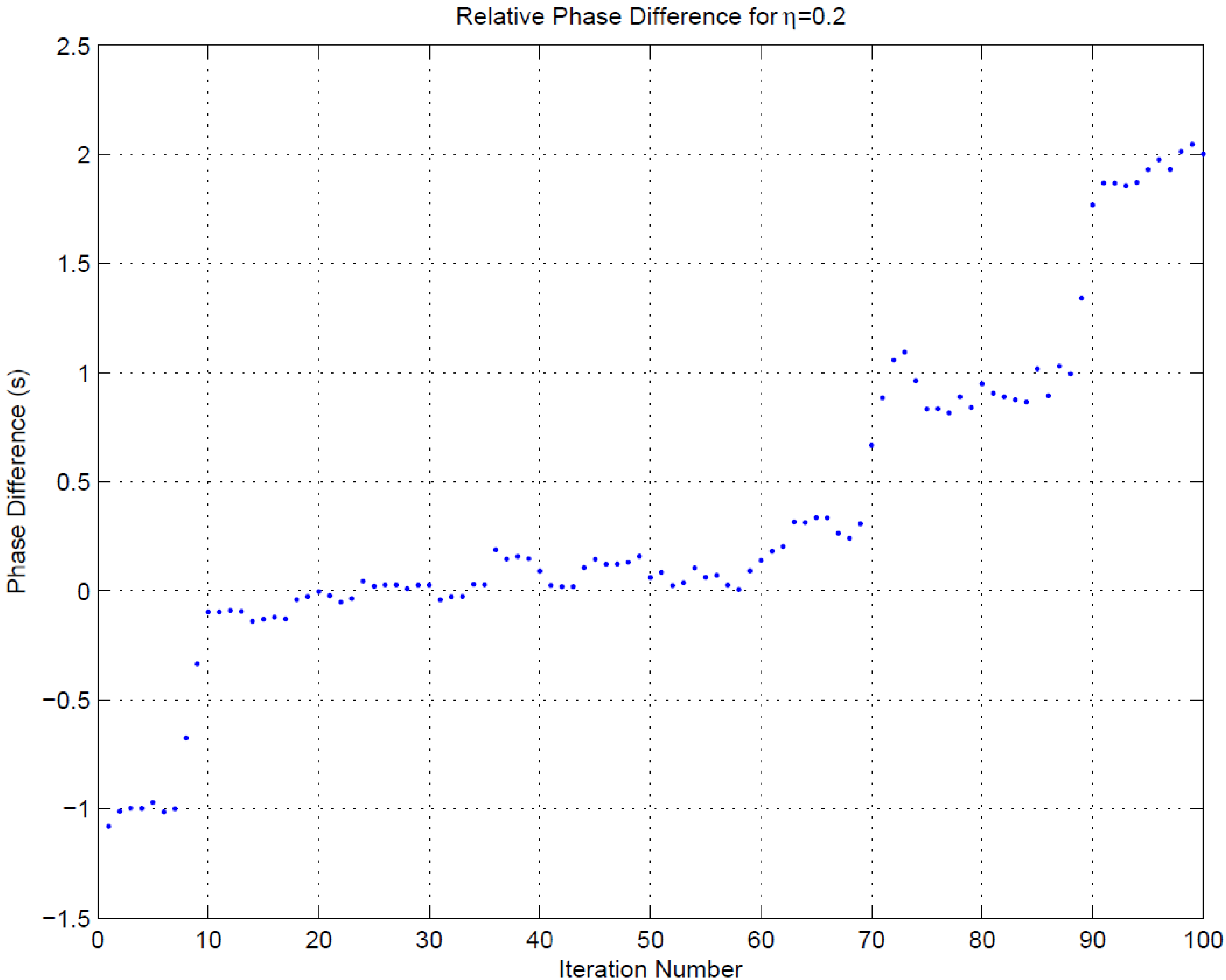
Relative Phase Difference for η=0.15
Phase Difference (s)
Iteration Number
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
0
10
20
30
40
50
60
70
80
90
100

Synchrony

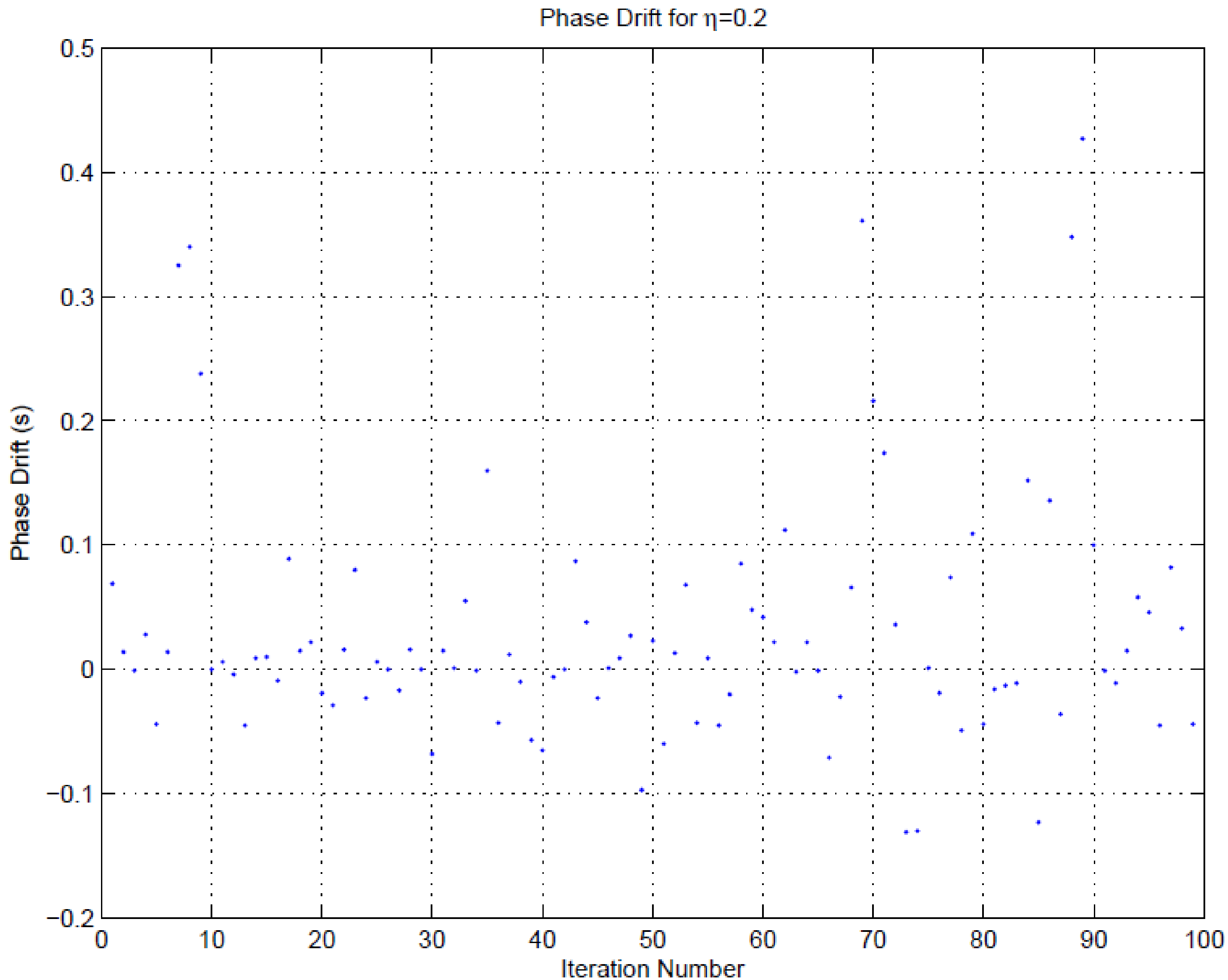


Phase Drift for η=0.15
Phase Drift (s)
Iteration Number
0.15
0.1
0.05
0
−0.05
−0.1
0
10
20
30
40
50
60
70
80
90
100

Shifts by 180°



Shifts by 180°



Simulation

Initialization(including frequency, coupling etc)

One cricket sings at its own frequency+some noise disturbation

the other cricket hear chirps from others,it boosts its state. If not, goes with its own frequency

Records down each time it chirp.

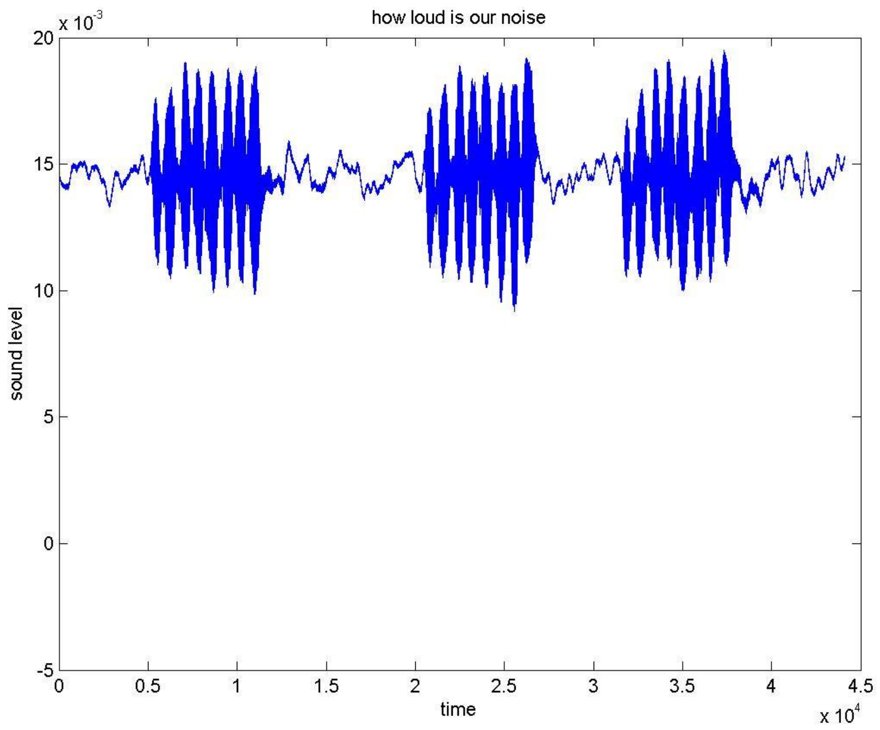
Compare to experiment

in simulation:

f (leader)~ f(follower)

boost strength ~ 0.3

threshold



In Experiment:

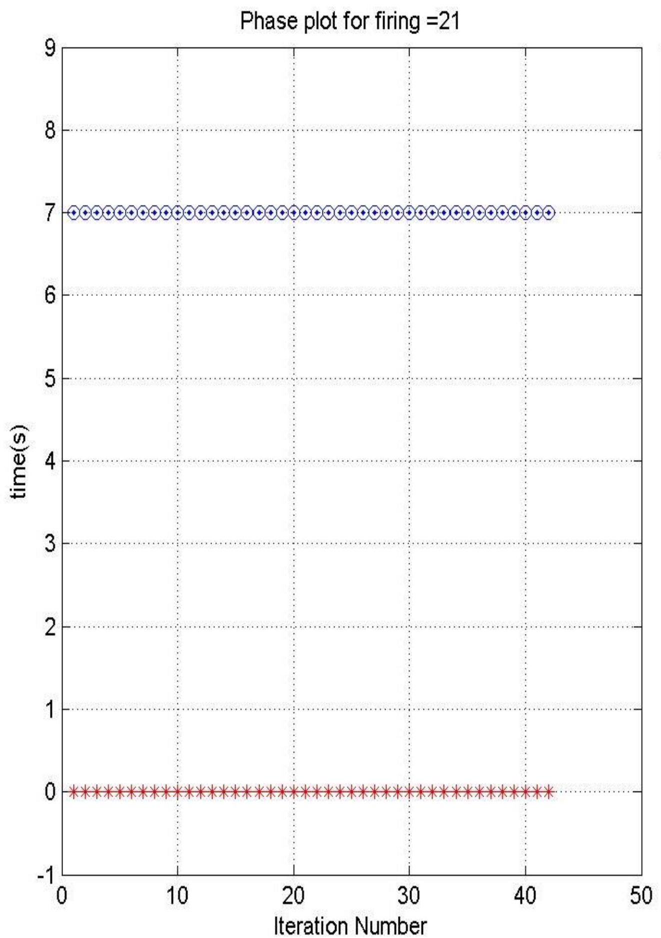
F(leader) ~ F(follower)

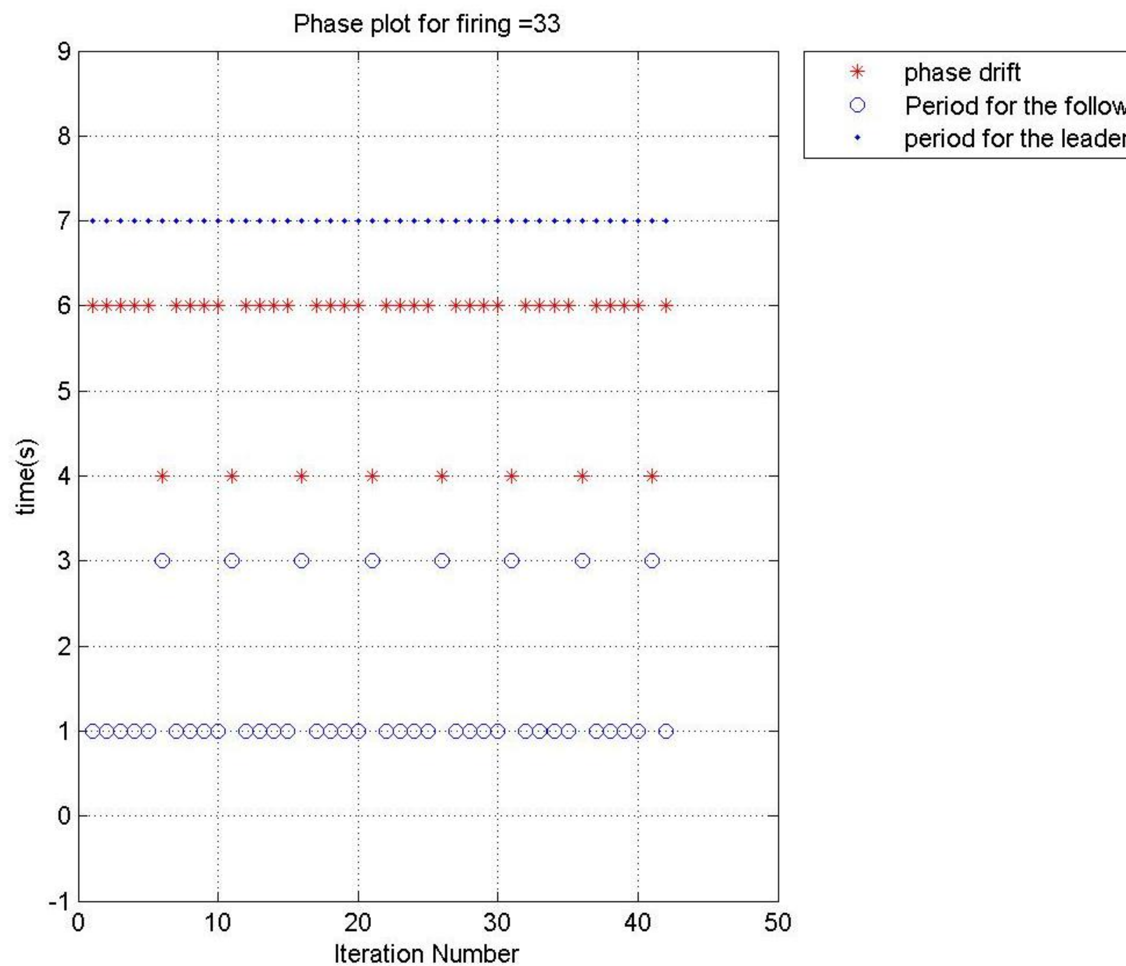
The noise ~ 0.02

boost strength ~ 0.1

Threshold = 1

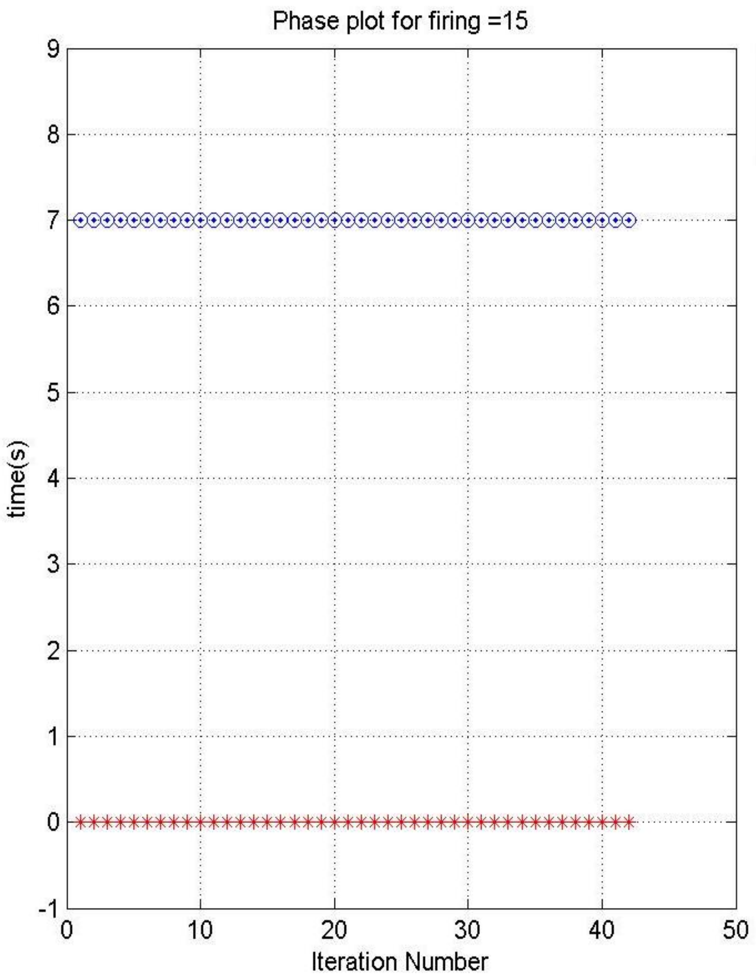
Stable disturbtion

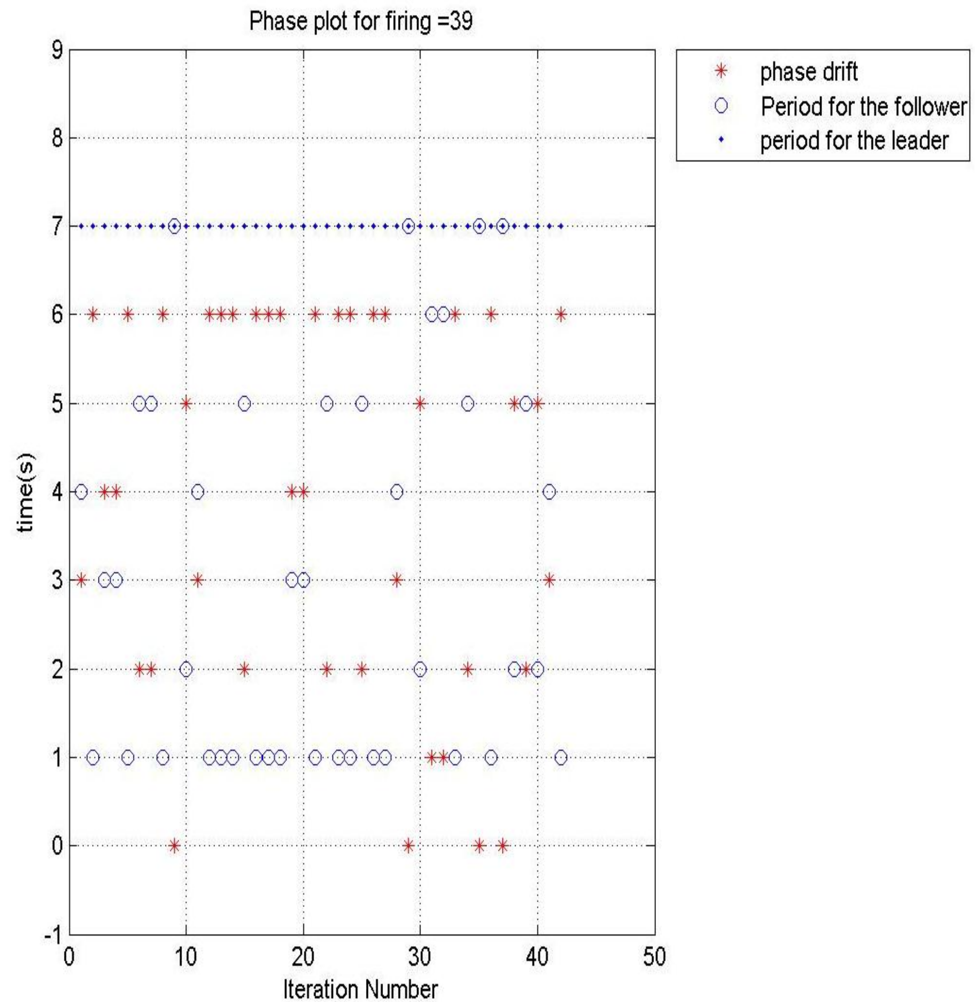




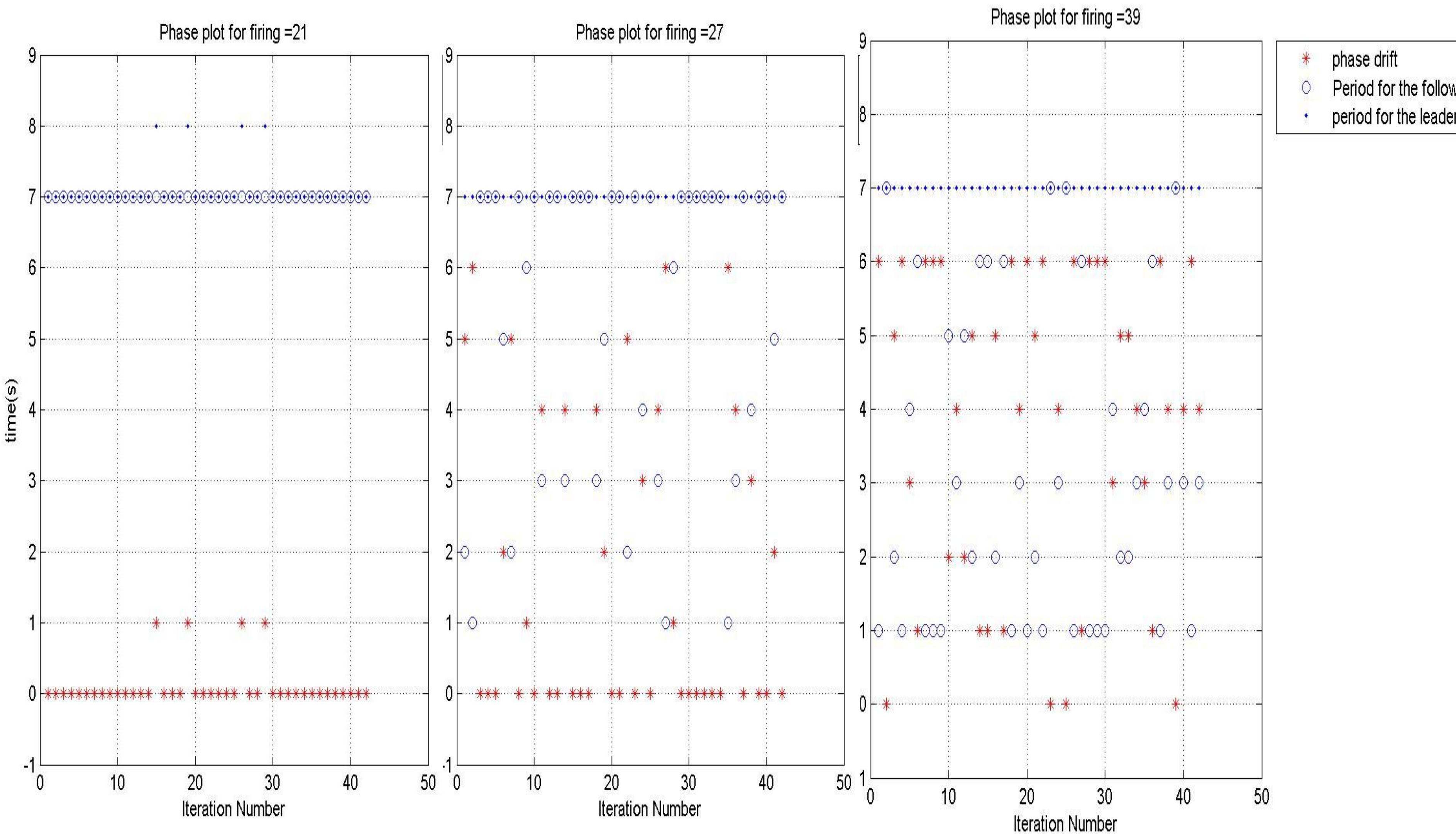
Boost = 27

Noise for one cricket?





Noise for two Cricket



Discussion

- This shows us that the leader-follower method leads to synchrony for most cases.
- This simple coupling is difficult to desync. It is very stable unless the disturbtion is about a order to the “threshold”.(large different natural frequency?)

Discussion: possible defects

1. extra unecessary boosts in experiments

Chirps Time >> recording time

How to choose a suitable time scale.

2. for the present model, phase in and out oscilation is very likely . Maybe a “boost-changeable” model?