



HAL
open science

Bifurcation Analysis of a Bistable Nonlinear Energy Harvesting System

Vinicius Lopes, Americo Cunha Jr

► **To cite this version:**

Vinicius Lopes, Americo Cunha Jr. Bifurcation Analysis of a Bistable Nonlinear Energy Harvesting System. São Paulo School of Advanced Sciences on Nonlinear Dynamics 2019, Jul 2019, São Paulo, Brazil. hal-02267133

HAL Id: hal-02267133

<https://hal.science/hal-02267133>

Submitted on 19 Aug 2019

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

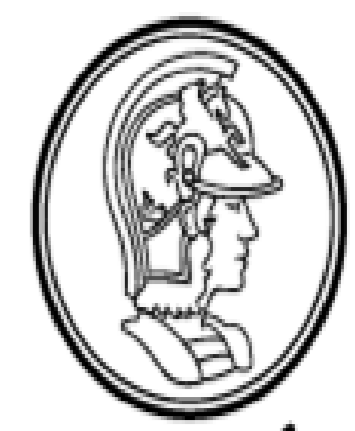


BIFURCATION ANALYSIS OF A BISTABLE NONLINEAR ENERGY HARVESTING SYSTEM

Vinicius Gonçalves Lopes, Americo Cunha Jr.

Universidade do Estado do Rio de Janeiro (UERJ)

Núcleo de Modelagem e Experimentação Computacional (NUMERICO)



INTRODUCTION

Energy harvesting devices recovers energy from secondary sources as mechanical vibration (piezoelectric), heat (thermoelectric) and light (photoelectric). Some examples among its most promising applications are supporting Internet of Things (IoT) devices, boarded small electro-electronic equipment or even pacemakers [3][4][5].

FIGURE 1 – Energy harvesting concept.

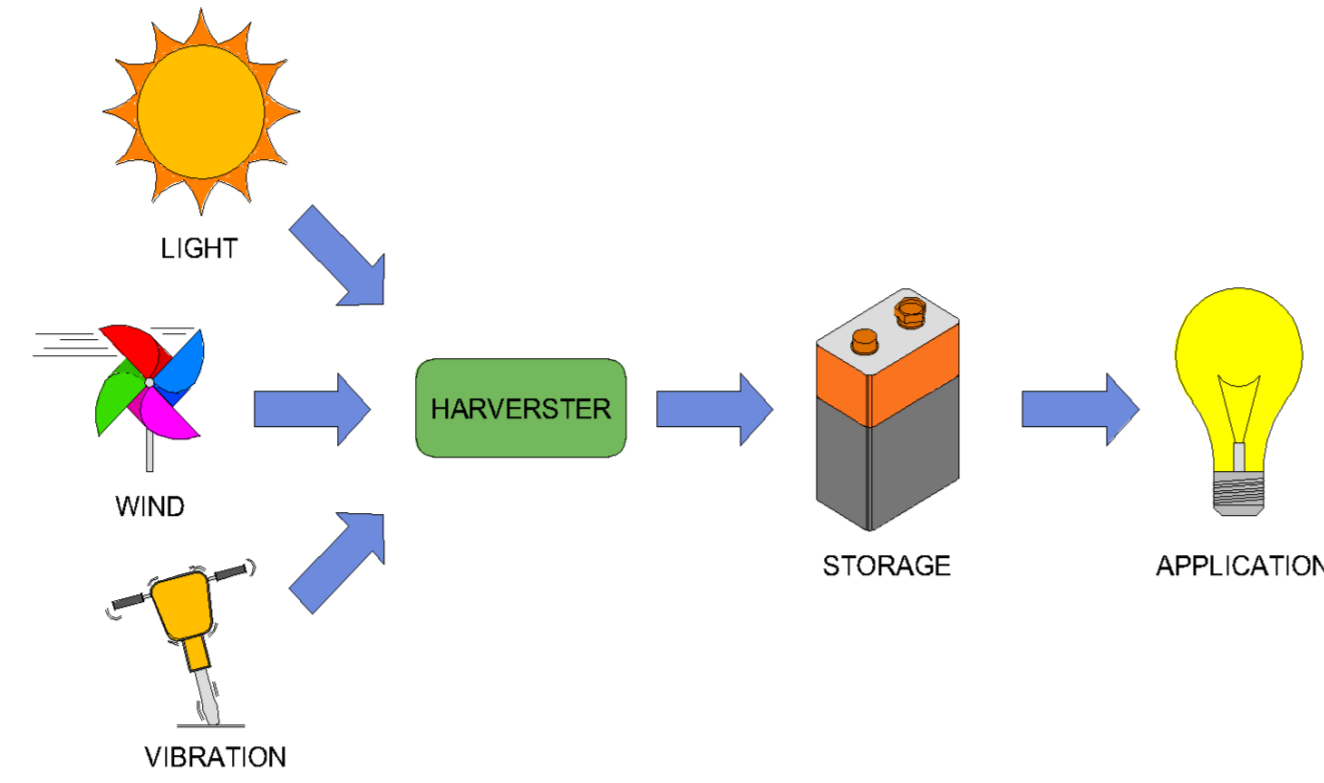
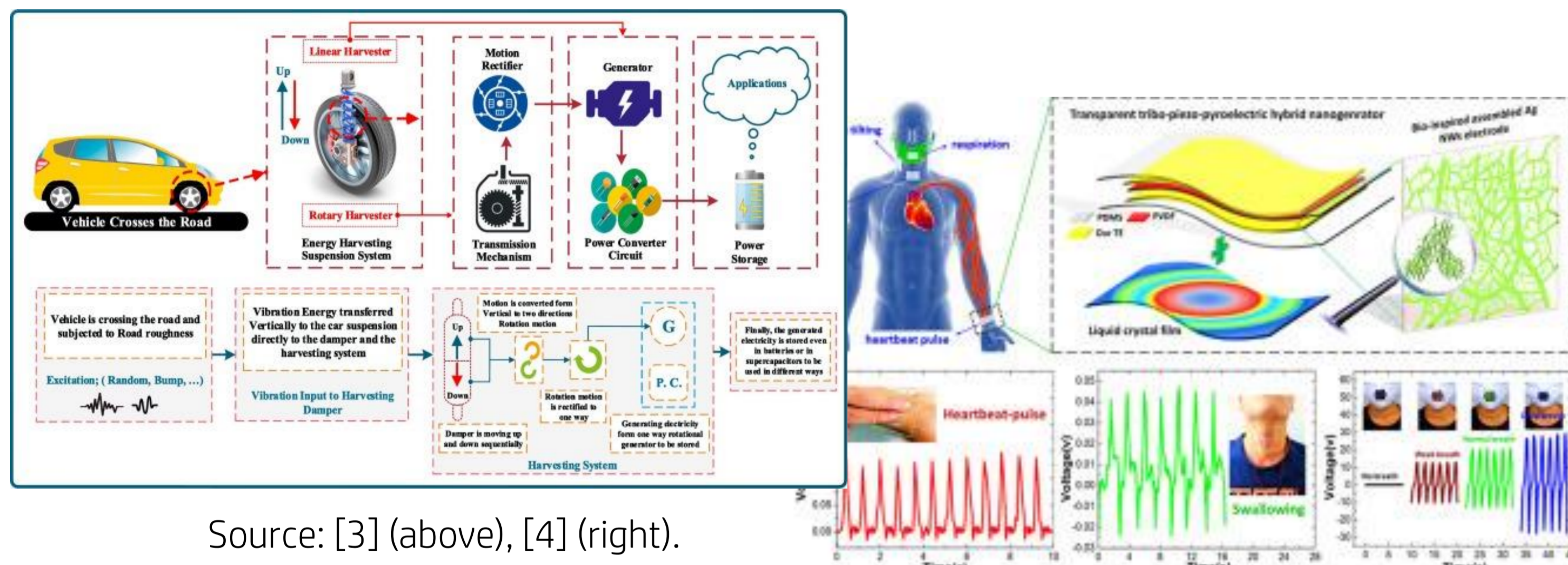


FIGURE 2 – Examples of energy harvesting technologies applications.



Source: [3] (above), [4] (right).

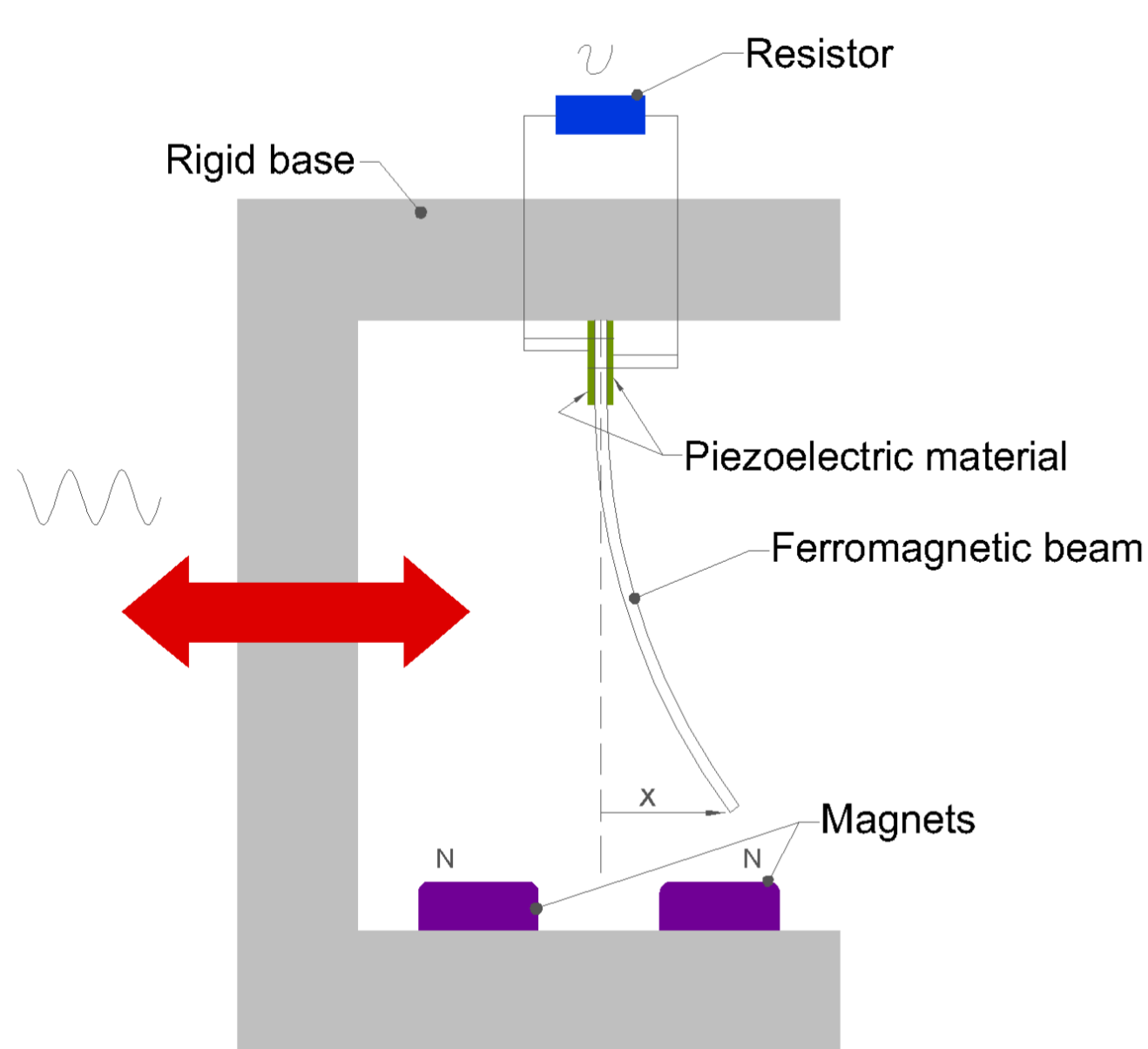
OBJECTIVES

The study aims to Identify:

- ✓ The forcing conditions which provides the best voltage regular responses;
- ✓ The excitation parameters which can be related with the chaos occurrence;
- ✓ The forcing parameters which provides the best voltage signals waveforms;
- ✓ The forcing parameters most able to improve the energy recovering;

MATHEMATICAL MODEL

FIGURE 3 – Energy harvester device [2]. $\ddot{x} + 2\xi\dot{x} - 0.5x(1-x^2) - \chi v = f \cos(\Omega t)$



$$\dot{v} + \lambda v + \kappa \dot{x} = 0$$

$$x(0) = x_0, \dot{x}(0) = \dot{x}_0, v(0) = v_0$$

- ξ – Dimensionless damping factor
- χ – Dimensionless mechanical coupling factor
- κ – Dimensionless electrical coupling factor
- λ – Inverse characteristic time constant
- f – Dimensionless forcing amplitude
- Ω – Dimensionless forcing frequency

CONCLUSIONS

- ✓ Time series analysis provides a detailed system dynamics overview;
- ✓ Forcing parameters sampling ordering affects the voltage results (hysteresis);
- ✓ Low amplitudes combined with low frequencies provides regular dynamics;
- ✓ Chaos occurrence can be related with the harmonic forcing frequency variations;

FUTURE STEPS

- ✓ Investigate the effects of a stochastic component combined with the harmonic external forcing;
- ✓ Investigate the electrical load model influence on the system dynamic response;
- ✓ Investigate the effects of chaos controlling strategies on energy recovering (Leonardo de la Roca - leonardo.roca@uerj.br);
- ✓ Experimental stand analysis;

AMPLITUDE ANALYSIS

FIGURE 4 – In the left, forward (blue scale) and backward (red scale) voltage bifurcation diagrams for $\Omega \in [0.1:0.1:0.9]$ and $0.01 \leq f \leq 0.3$; in the right, diagrams sampled for $\Omega = 0.8$.

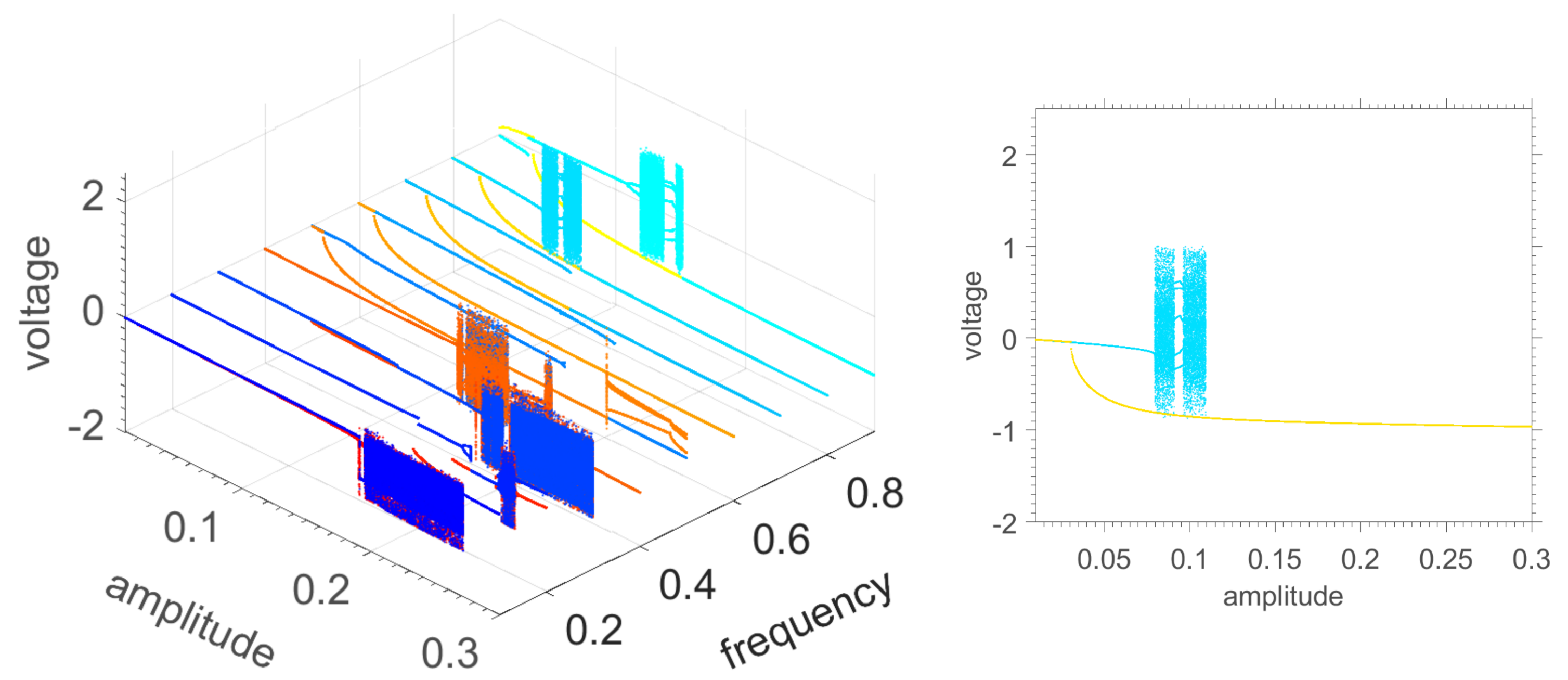
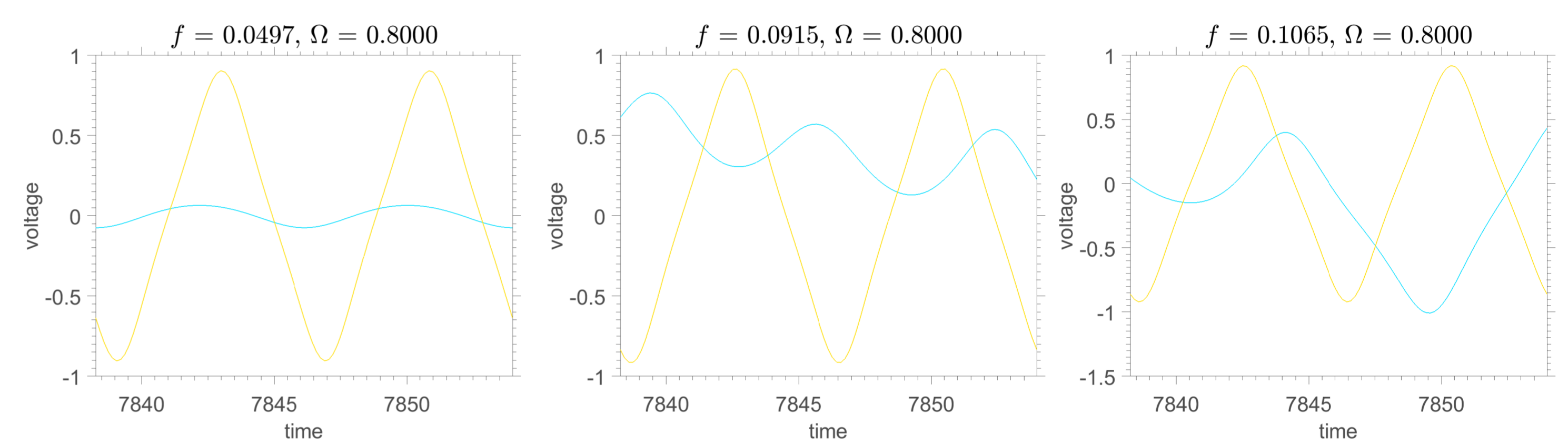


FIGURE 5 – Sampled voltage time series from diagrams for $\Omega = 0.8$ and different amplitudes.



FREQUENCY ANALYSIS

FIGURE 6 – In the left, forward (blue scale) and backward (red scale) voltage bifurcation diagrams for $f \in [0.019:0.032:0.275]$ and $0.1 \leq \Omega \leq 1.4$; in the right, diagrams sampled for $f = 0.083$.

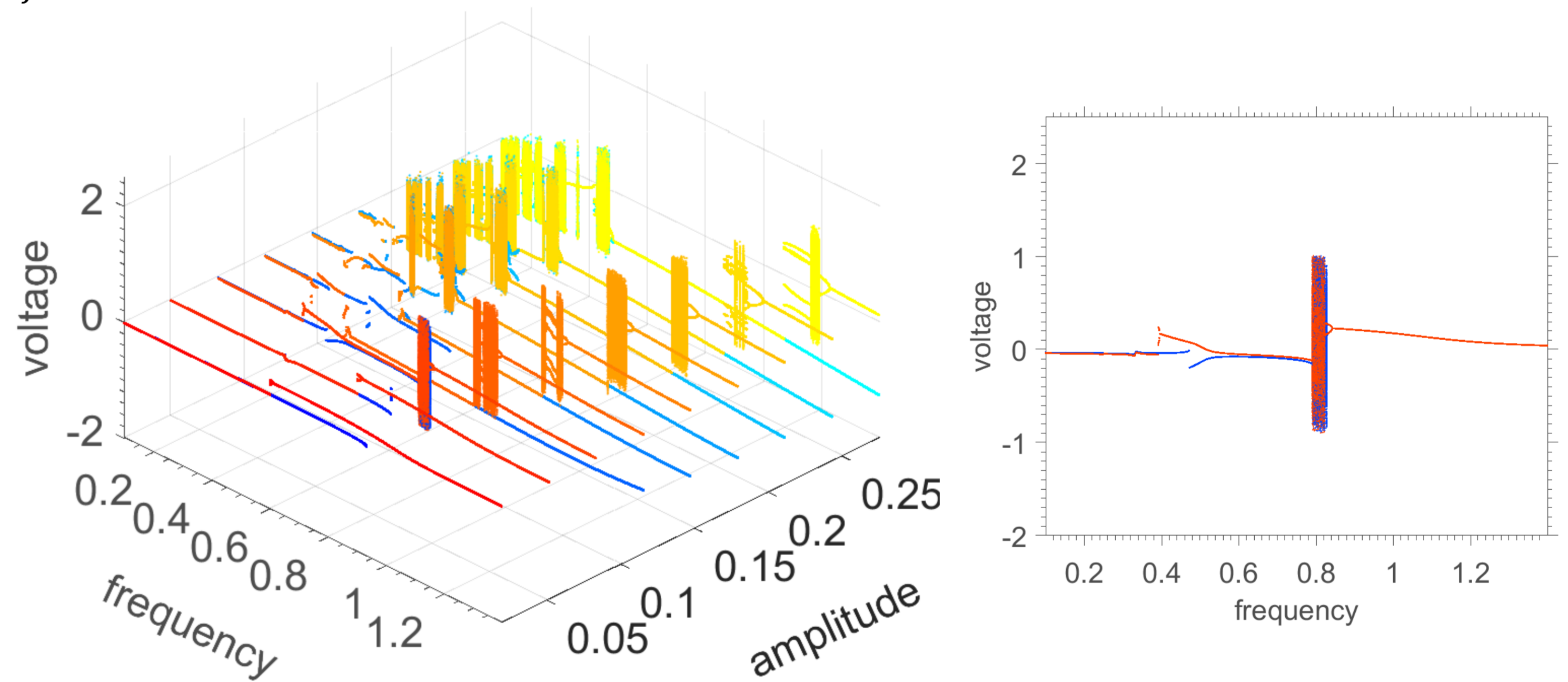
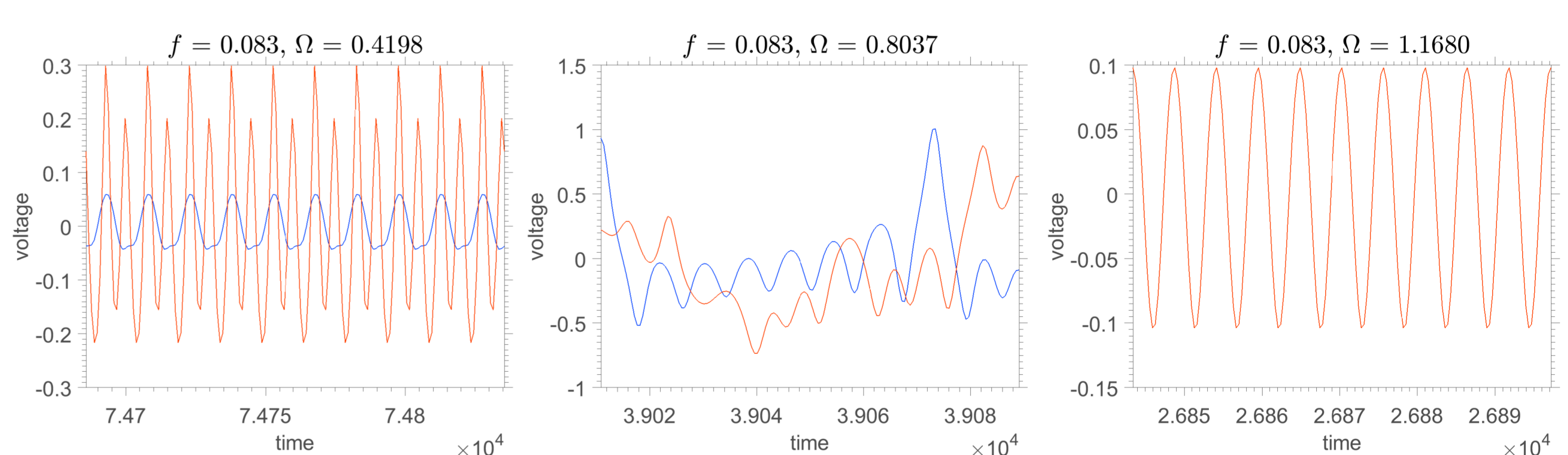


FIGURE 7 – Sampled voltage time series from diagrams for $f = 0.083$ and different frequencies.



REFERENCES

- [1] F. Cottone, H. Vocca and L. Gammaitoni, Nonlinear Energy Harvesting, In: Physical Review Letters, 102: 080601, 2009. (<https://doi.org/10.1103/PhysRevLett.102.080601>)
- [2] A. Erturk, J. Hoffmann, and D. J. Inman, A piezomagnetoelastic structure for broadband vibration energy harvesting, In: Applied Physics Letters, 94:254102, 2009 (<http://dx.doi.org/10.1063/1.3159815>)
- [3] M. A. A. Abdulkareem et al, Vibration energy harvesting in automotive suspension system: A detailed review, In: Applied Energy, 229, 2018 (<https://doi.org/10.1016/j.apenergy.2018.08.030>)
- [4] J. Sun and T. Yang and C. Wang and L. Chen, A flexible transparent one-structure tribo-piezoelectric hybrid energy generator based on bio-inspired silver nanowires network for biomechanical energy harvesting and physiological monitoring, In: Nano Energy, 48, 2018 (<https://doi.org/10.1016/j.nanoen.2018.03.071>)
- [5] V. G. Lopes, J. V. L. L. Peterson, A. Cunha Jr., Nonlinear characterization of a bistable energy harvester dynamical system. Mohamed Belhaq, In: Topics in Nonlinear Mechanics and Physics: Selected Papers from CSNDD 2018, 228, Springer International Publishing, 2019, Springer Proceedings in Physics (DOI:10.1007/978-981-13-9463-8_3)