

Bio-Inspired Electromagnetic Protection Based on Neural Information Processing

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Abstract

Electronic systems are vulnerable in electromagnetic interference environment. Although many solutions are adopted to solve this problem, for example shielding, filtering and grounding, noise is still introduced into the circuit inevitably. What impresses us is the biological nervous system with a vital property of robustness in noisy environment. Some mechanisms, such as neuron population coding, degeneracy and parallel distributed processing, are believed to partly explain how the nervous system counters the noise and component failure. This paper proposes a novel concept of bio-inspired electromagnetic protection making reference to the characteristic of neural information processing. A bionic model is presented here to mimic neuron populations to transform the input signal into neural pulse signal. In the proposed model, neuron provides a dynamic feedback to the adjacent one according to the concept of synaptic plasticity. A simple neural circuitry is designed to verify the rationality of the bio-inspired model for electromagnetic protection. The experiment results display that bio-inspired electromagnetic protection model has more power to counter the interference and component failure.

Keywords: biological nervous system, robustness, population coding, bio-inspired electromagnetic protection model, neural circuitry

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1 Introduction

The ultimate victims of electromagnetic interference are electronic systems. Noise coupled to the circuit disturbs the system and even causes some components to malfunction^[1]. The traditional protection methods include shielding, filtering and electromagnetic protection devices^[2,3]. But each of them has drawback in complex electromagnetic environment. It is difficult to guarantee that the protected circuit is not disturbed due to multifarious possible mechanisms for coupling of electromagnetic to circuit. Some scientists conduct a series of measurements of such noise voltage coupled into digital chips^[4,5]. Electrostatic Discharge (ESD) pulse causes noise voltage on net leading to bit error, even though ESD protection circuit has extremely limited the level of interference. Obviously, the problem caused by electromagnetic interference can not be totally solved just relying on traditional protection methods.

Noise permeates every level of the nervous system, from single neuron to the whole system^[6]. That is, the information processed by nervous system is usually blurry and imprecise. However, the noise seems not taking so much trouble to neural information processing in contrast to electronic system^[7,8]. Nervous system is considered to possess some kinds of principles to counter noise for its long time evolution under the constraint of noisy environment. First, the nervous system has a unique information code, such as, frequency coding^[9] and population coding^[10]. An observed advantage of population coding is robustness. The loss or interference of neuron will not influence the neural coding. Second, Noppeney *et al.* argued that the multiple degenerate neuronal systems can maintain and recover cognitive function after focal cortical damage^[11]. Edelman *et al.* defined degeneracy as the ability of elements that are structurally different to perform the same function^[12]. Third, feedback is considered to be a basic

principle endowing the nervous system with stability. Excitatory or inhibitory input from other neurons is a cardinal feedback for neuron^[13]. The last, maybe the most important one, is synaptic plasticity. Hebb proposed the hypothesis of synaptic plasticity which underlines information storage, learning and adaptive behavior in brain^[14]. With the advance of modern electrophysiological techniques, substantial evidence of synaptic plasticity has been found^[15,16]. This structural plasticity could not only provide a boost in the memory storage capacity but also be involved in recovery from brain injury^[17,18].

The bio-inspired electromagnetic protection is a new electromagnetic protection method which is different from traditional ways for its special purposes^[19,20]. It aims at making the circuit removing noise relying on its own mechanism rather than assistant circuit. We explore the guidelines for designing electronic systems with high ability of countering electromagnetic interference and component failure in a bionic way^[21]. Through mimicking the mechanism of robustness of nervous system, three problems are hopefully solved:

(1) The system gets the satisfactory results in the presence of noise in input signal from the external environment.

(2) The system gets the satisfactory results even when noise or imprecision exists between its internal subsystems.

(3) The system still keeps its function once the failure of internal components happens.

The bio-inspired electromagnetic protection here is not a substitute of traditional electromagnetic protection method. It focuses on the mechanism why the biological system is robust in interference environment. It is believed that the bio-inspired method will be a perfect complement of traditional way for electromagnetic protection.

2 The bio-inspired electromagnetic protection model

The resonance in the visual cortex of mammal suggests that a large number of neurons participate in the information processing at the same time^[22]. That is an evidence of neuron population coding. The neurons with the similar characteristic assemble together to improve the robustness of signal transmission. Firstly, the activities of neuron rely not only on external stimuli but also

on the activities of other neurons in population. The coding and processing of information are finished by the cooperation of neuron population. Secondly, neuronal population coding includes some dynamic processes. Adjacent neurons in anatomy can form cell populations dynamically through functional connection. The functional population will change or dissolve according to the mission of neurons. For a single neuron, it has chance to constitute different population with adjacent cells. The dynamic structure is beneficial for enhancing the efficiency and robustness of information processing in neural circuit.

In this section, a Bio-inspired Electromagnetic Protection Model (BEPM) is presented based on the mechanism of population coding, feedback and synaptic plasticity. The bio-inspired model tries to mimic the neuronal population coding to transform the voltage or current signal into neural pulse signal. The resonance frequency of neuronal population denotes the value of input signal. We attempt to obtain a robust system from coding activities of dynamic element assembly. The basic function is described in Fig. 1.

The structure of BEPM is illustrated in Fig. 2. The BEPM is constituted by two kinds of component including neuron and synapse. A circle denotes a neuron, and a line means a synaptic connectivity between two neurons. The lines are not displayed between neurons in our model if they are not in the same neuron population. The BEPM is a matrix of neuron and synapse. The basic function of neuron is signal conversion. It is a transducer

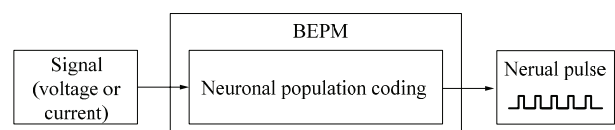


Fig. 1 Function of BEPM.

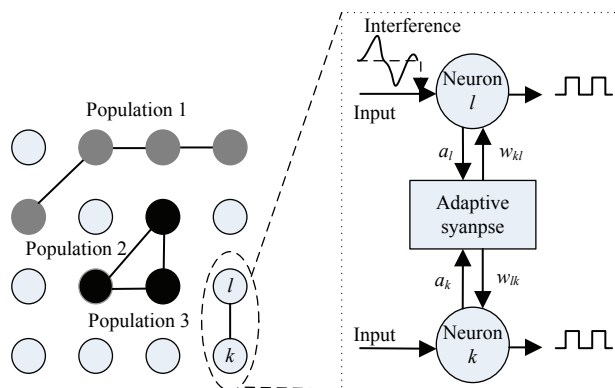


Fig. 2 Structure of BEPM.

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