Dan Wu, Chao-yi Li, Jie Liu, Jing Lu, De-zhong Yao, 2014. Scale-free brain ensemble modulated by phase synchronization. *Journal of Zhejiang University-SCIENCE C (Computers & Electronics)*, **15**(10):821-831. [doi:10.1631/jzus.C1400199]

Scale-free brain ensemble modulated by phase synchronization

JZUS-C (Comput. & Electron)

Key words: Brainwave, Ensemble, Music, Scale-free, Synchronization

Corresponding author: De-zhong Yao
E-mail: dyao@uestc.edu.cn

Introduction

- EEG has been a useful tool for monitoring the neural electrical activities of the brain in a non-invasive way. We can directly ‘perceive’ what the brain ‘sings’ by brainwave music.
- There are three categories of brainwave music. The first is called “sonification”, the second is the musical application of brain-computer interface (BCI), and the third is scale-free brainwave music (SFBM).
- The power law, or scale-free, exists at almost all levels of neural physiology, including EEG. It appears applicable to music, audio signal and the number of note occurrences which show a power law distribution.

JZUSC(Comput.&Electron.)

Method (I)

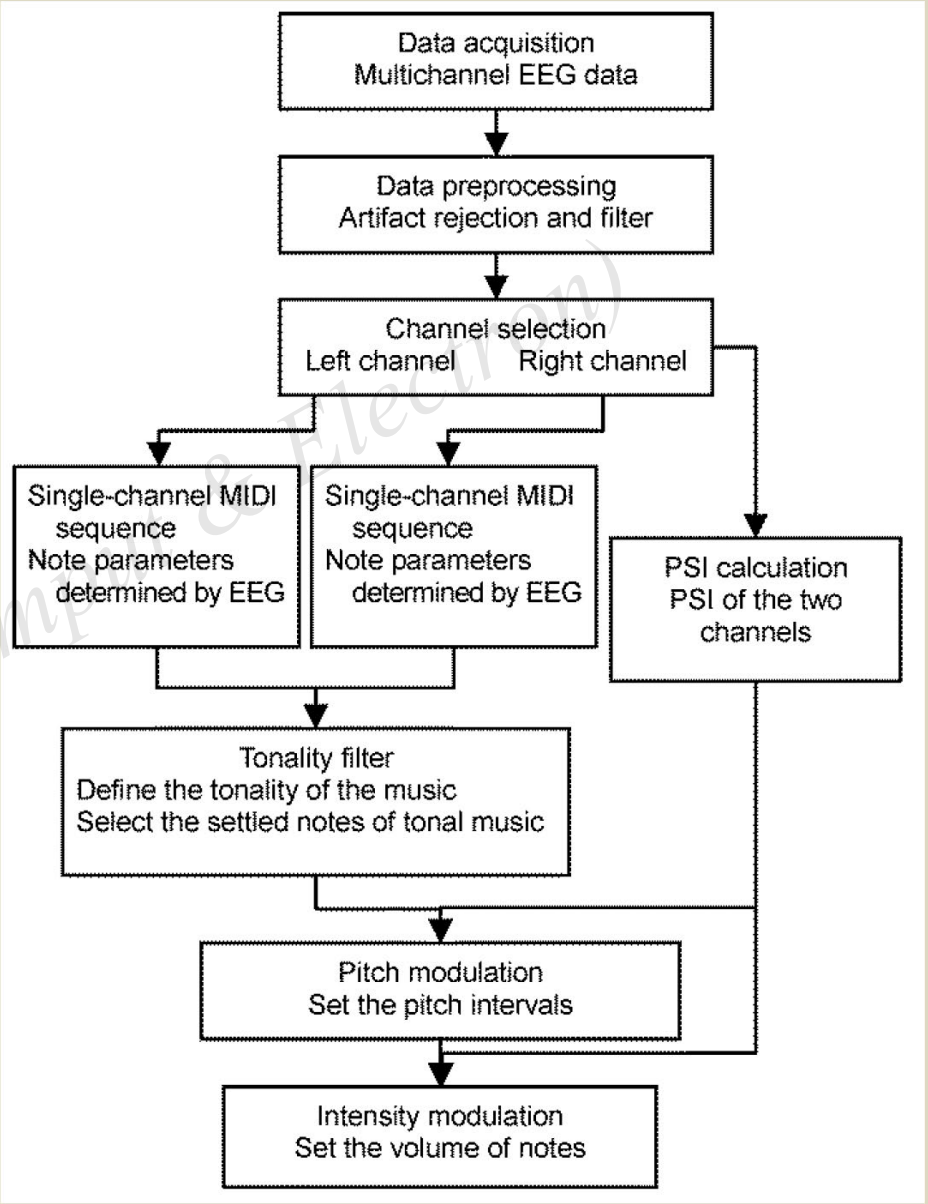
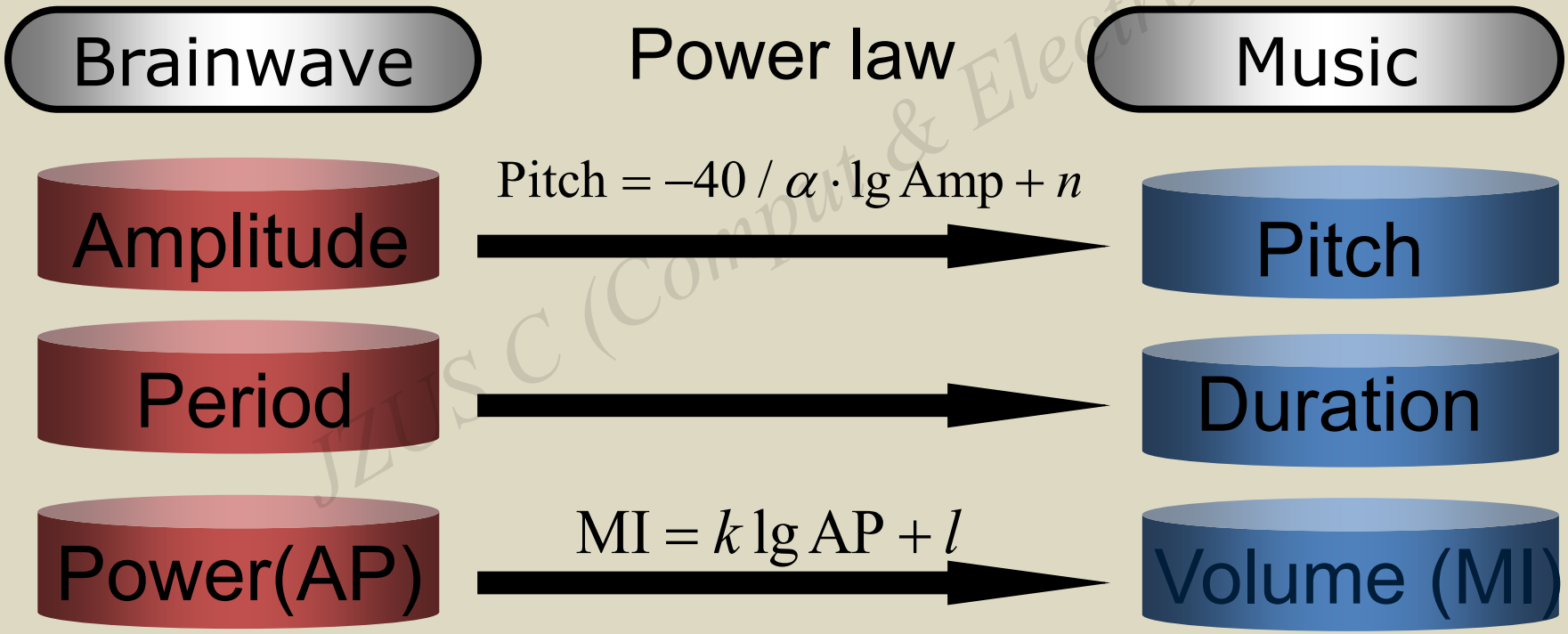


Fig. 1 Signal flow of the scale-free brainwave chorus music generation

Method (II)

1. Translation from EEG to music:



JZUSC (Comput. & Electron.)

Method (III)

2. Phase synchronous index (PSI) calculate:

Step 1: compute the instantaneous phases $\phi_x(t)$ and $\phi_y(t)$

$$\varphi_x(t) = \arctan\{(\int_{-\infty}^{\infty}[x(\tau)/\pi(t-\tau)]\mathrm{d}\tau)/x(t)\}$$

Step 2: define the phase difference

$$\Phi_{xy}(t) = \left|\varphi_x(t) - \varphi_y(t)\right|$$

Step 3: calculate PSI

$$\gamma \equiv \left| < \mathrm{e}^{\mathrm{i}\Phi_{xy}(t)} >_t \right| = \sqrt{< \cos\Phi_{xy}(t) >_t^2 + < \sin\Phi_{xy}(t) >_t^2}$$

JZUSC (Comput & Electron)

Method (IV)

3. Tonality filter and pitch modulation:

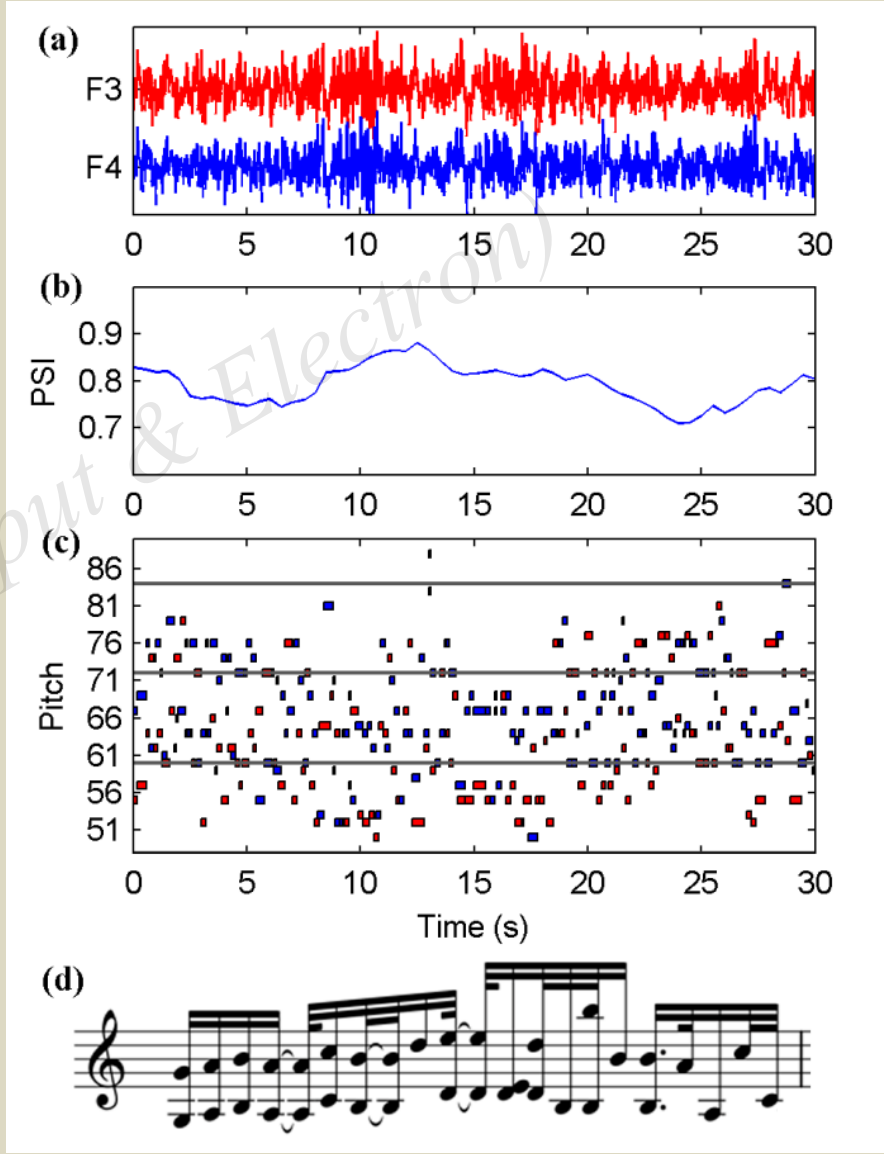
(1) Verify the importance order of the two notes from the two MIDI sequences. The smaller one is settled.

(2) If the two notes have the same importance order, the one with a greater duration is chosen.

(3) If the importance order of the two notes are both 8, and PSI>0.2, the note of the left hemisphere is set to the nearest tone notes.

JZUS C (Comput & Electron)

Major results (I)

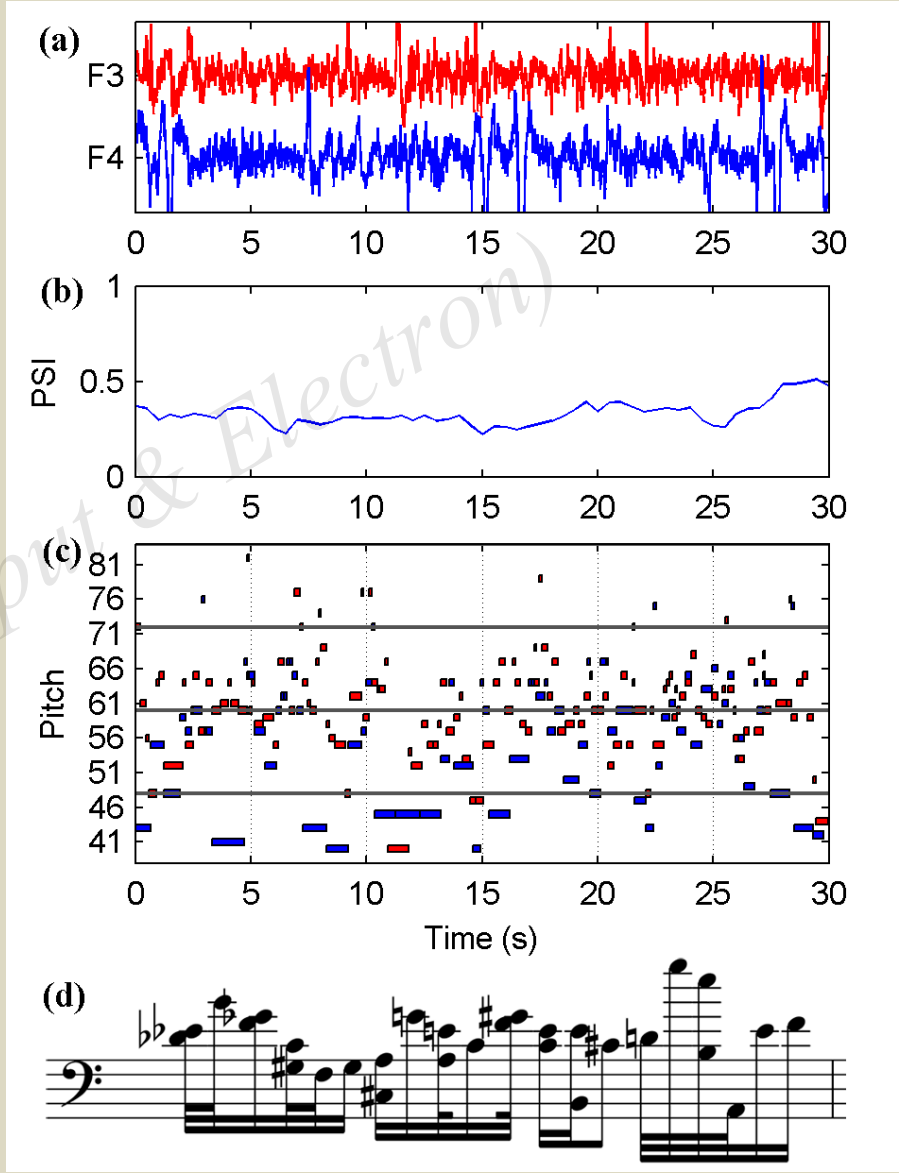


EEG and musical notes obtained from F3-F4 electrodes with eyes closed: (a) The EEG data from electrodes F3 (left hemisphere) and F4 (right hemisphere); (b) the PSI of the two channels; (c) the notes of the brain music (red from F3 and blue from F4); (d) example of the music scores

JZUSC (Comput & Electron)

Major results (II)

EEG and musical notes obtained from F3-F4 electrodes with eyes open: (a) the EEG data from electrodes F3 (left hemisphere) and F4 (right hemi-sphere); (b) the PSI of the two channels, (c) the notes of the brain music (red from F3 and blue from F4); (d) example of the music scores



JZUSC (Comput & Electron)