A HHT-based Time Frequency Analysis Scheme in Clinical Alcoholic EEG Signals

Chin-Feng Lin [1], Shan-Wen Yeh[1], Yu-Yi Chien [2] ,Tsung-Ii Peng[2] ,Jung-Hua Wang[1] ,and Shun-Hsyung Chang[3]

[1]Department of Electrical Engineering
National Taiwan-Ocean University
e-mail: lcf1024@ mail.ntou.edu.tw
Keelung, Taiwan ROC

[2]Department of Neurological Division
Chang Cung Memorial Hospital, Keelung Branch
e-mail: tipeng@adm.cgmh.org.tw
Keelung, Taiwan ROC

[3]Department of Microeletronic Engineering
National Kaohsuing Marine University
e-mail: shchang@mail.nkmu.edu.tw
Kaohsiung, Taiwan ROC

Abstract: -In this paper, a Hilbert-Huang Transformation (HHT)-based time frequency scheme is applied to the analysis of clinical alcoholic and normal control FP1 electroencephalogram (EEG) signals. The differences in the responses of the EEG signals, the intrinsic mode function (IMF), instantaneous frequency (IF), marginal frequency (MF), and the Hilbert spectrum between the simulation results of the clinical EEG signals of the alcoholic and control groups are discussed. When comparing the clinical EEG signals of the alcoholic and control groups, the EEGs of the control group of picture observers did not appear to indicate significantly larger voltage. The EEG signals of the alcoholic group in the experiment suggested that when they were exposed to the stimulus, brain cells were stimulated and emitted higher voltage. From these discussion, we can recognize IMFs, IFs, Hilbert Marginal frequency, and Hilbert spectrum of EEG signals of an alcoholic and a normal observers to define an alcoholic illness.

Key-Words: - Hilbert-Huang Transformation (HHT)time frequency analysisalcoholic EEG clinical signalsintrinsic mode functionHilbert spectrum

1 Introduction

Mobile telemedicine and biomedical signal processing are interest research topics [1-28]. The discussion of mobile telemedicine systems and chaos-based encryption scheme of clinical signals has been scrupulously studied in our earlier work [16-26]. In this paper, we discuss a Hilbert-Huang Transformation (HHT)-based time frequency analysis scheme for clinical alcoholic EEG Signals. There is a difference between the measurement of biological signals of the human body by using electronic instruments and conventional intrusive methods; electronic instruments induce little trauma to the body and cause less stress to the patient by inflicting pain in addition to that caused by an illness. Examination of clinical electroencephalogram (EEG) signals is a current topic of interest. Prof. Hamsberger in Germany was the first to record EEG signals in 1927. In 1934, Adria and Matthews discussed the correlation between the EEG signal and brain activity. Various physiological and pathological phenomena affect the characteristics of EEG signals. Therefore, critical clinical information can be obtained from observation and analysis of EEG signals in cases of brain tumors or hemorrhage, cerebral infarct, head injury, encephalitis, coma, seizure disorders (epilepsy), sleep disorders (narcolepsy), and alcoholism. Presently, EEG signal characteristics of various diseases are being explored. In this study, the characteristics of brain wave detected in cases of alcoholism are determined by analysis and discussion of the measured clinical EEG signals. A set of pictures is used to visually stimulate the cell discharge of the alcoholic brain, the potential change is accordingly observed, and the brain wave data are compared with those of a control group. The general EEG signal characteristics of alcoholism are determined using delicate analytical tools, supplementing observations of clinical behavior. At present, the analytical techniques frequently used in dealing with the EEG signal temporal frequency are as follows: short-time Fourier transform [1-5], wavelet-transform [6] and Hilbert-Huang Transformation (HHT) [7-14]. For conventional Fourier transform, the condition required for the signal must be a linear and stationary data string, for a sufficiently long period, and predefined. It is difficult for the Fourier transform to provide good spectrum resolution when there is a large variation in frequency within a short period. The solution is to define a new temporal frequency space waveform description format. The major concept of the transformation is to formulate a time frame for calculating the spectrum of the data string desired for processing within a unit of time; the time frame should be narrow enough to provide good resolution. Wavelet transform is defined as a gauss envelope, initially with a zero mean. Changing the scale of the constant will change the frequency width and time space result; the frame stays constant but with a larger or smaller shape. Short-time Fourier transform uses a constant window width; in contrast, theoretically, wavelet-transform uses a shorter window width at high frequency and a longer window width at low frequency. However, the wavelet-transform solves the window width problem of short-time Fourier transform. The wavelet-transform frequency resolution phase depends on basis function. In addition, the HHT technique was used in the development of an alcoholism syndrome EEG signal temporal frequency analysis technique, acquiring the temporal frequency characteristics vector of the EEG signal. The HHT is extensively used in frequency correlation of non-stationary, non-linear characteristic or temporal-spatial characteristic signal analysis.

2.A HHT-based Time Frequency Analysis Scheme for Clinical Alcoholic EEG Signals

EEG signal frequency can be divided into four categories: β wave (conscious), α wave (bridge conscious), θ wave (subconscious), and δ wave (conscious-less). These combinations of consciousness form a person's internal behavior, emotion, and learning performance. The HHT temporal frequency analysis technique uses empirical mode decomposition (EMD) and the decomposition of the intrinsic mode function (IMF), and conducts the Hilbert Transformation (HT), developing an instantaneous frequency change, and instantaneous amplitude, which takes multiple channels into account, resulting in a time and frequency dependent analysis of variation. The procedure for analyzing the IMF by EMD is described as follows:

Step 1: initial and assume $r_o = x(t)$ and i=1;

Step 2: analyze the ith IMF;

(a) initial and assume $h_{i(k-1)} = r_i$, k=1;

(b) analyze $h_{i(k-1)}$ the local maximum and minimum;

(c) construct $h_{i(k-1)}$ the upper limit and lower limit envelope through addition sampling;

(d) calculate mean $m_{i(k-1)}$ of the upper limit and lower limit envelope $h_{i(k-1)}$;

(e) $h_{ik} = h_{i(k-1)} - m_{i(k-1)}$;

(f) If h_{ik} is IMF, then $IMF_i = h_{ik}$; or go to step (b) and k = k+1;

Step 3: define $r_{i+1} = r_i - IMF_i$;

Step 4: If r_{i+1} has at least two extreme values, go to step 2 or the analysis procedure is finished and r_{i+1} is the residue signal;

Where IMF is defined by two conditions:
Condition 1: the difference of the figure crossing with zero and the local extreme value of the entire data shall be equal or 1.
Condition 2: the mean of any point is the average of local envelope maximum and minimum.

In addition, the HHT-based time frequency analysis scheme has 4 assumptions:
Assumption 1: At least two extreme points for signals: max. and min.
Assumption 2: selection of scale size of the characteristic time rests at the extreme point and the temporal interval.
Assumption 3: provided that the data to be analyzed have no extreme values but contain identifiable points that can be expressed as extreme points of single or multiple analyses, accompanying the increase in the number of analyses, the max/min points become significant.
Assumption 4: the final result should be the sum of the above stated composition.

Thus, the single channel EEG wave can be defined as function *x(t)*, whereas function *x*(*t*) analyzes the IMF by using the Empirical Mode function, described as:

$$x(t) = \sum_{i=1}^{n} IMF_i(t) + r(t) \qquad (1)$$

$IMF_i(t)$: the ith IMF

r(t): attribution function(residue)

Then

$$z(t) = x(t) + jy(t) = x(t) + jHT\{x(t)\} = a(t)e^{j\theta(t)}$$

HT{}:Hilbert Transformation

$$a(t) = \sqrt{x^2(t) + y^2(t)}$$

$$\theta(t) = \arctan(\frac{y(t)}{x(t)}) \qquad (2)$$

Thus, the IF of a single channel EEG signal can be analyzed as:

$$f = \frac{1}{2\pi}\frac{d\theta(t)}{dt} \qquad (3)$$

By using the HHT-based time frequency analysis technique, the time frequency characteristic vector of the EEG signal for alcoholism can be acquired, and the frequency characteristic, amplitude characteristic, time depended temporal-spatial frequency correlation, and correlation of the multiple channel EEG signal can be analyzed. Furthermore, it is possible to determine statistically common and abnormal points and generalize a standard in comparison with a normal sample, augment the efficiency of observation, and analyze the alcoholic EEG signal to enhance the quality of the physician's clinical diagnosis of alcoholism.

3.Simulation Results

In this simulation, references [15] from the alcoholic EEG signal database were adopted. Database format: multiple electrodes positioned in time sequence record the EEG signal state of the control group and the alcoholic group. Experimental method: attach 64 sensors (representing 64 channels) to the skull skin; the sampling rate of each channel is 256 per second. Experimental scenario: alcoholic group vs. control group; each individual watched a picture for 1 second in every round. The pictures used were as follows: 1980 Snodgrass and Vanderwart picture set [16]. Figure 1 is an FP1 EEG signal presented by a normal observer watching a picture (stimulant). Figure 2 is an FP1 EEG signal presented by an alcoholic observer watching a picture (stimulant). When comparing the signals, the EEGs of the normal

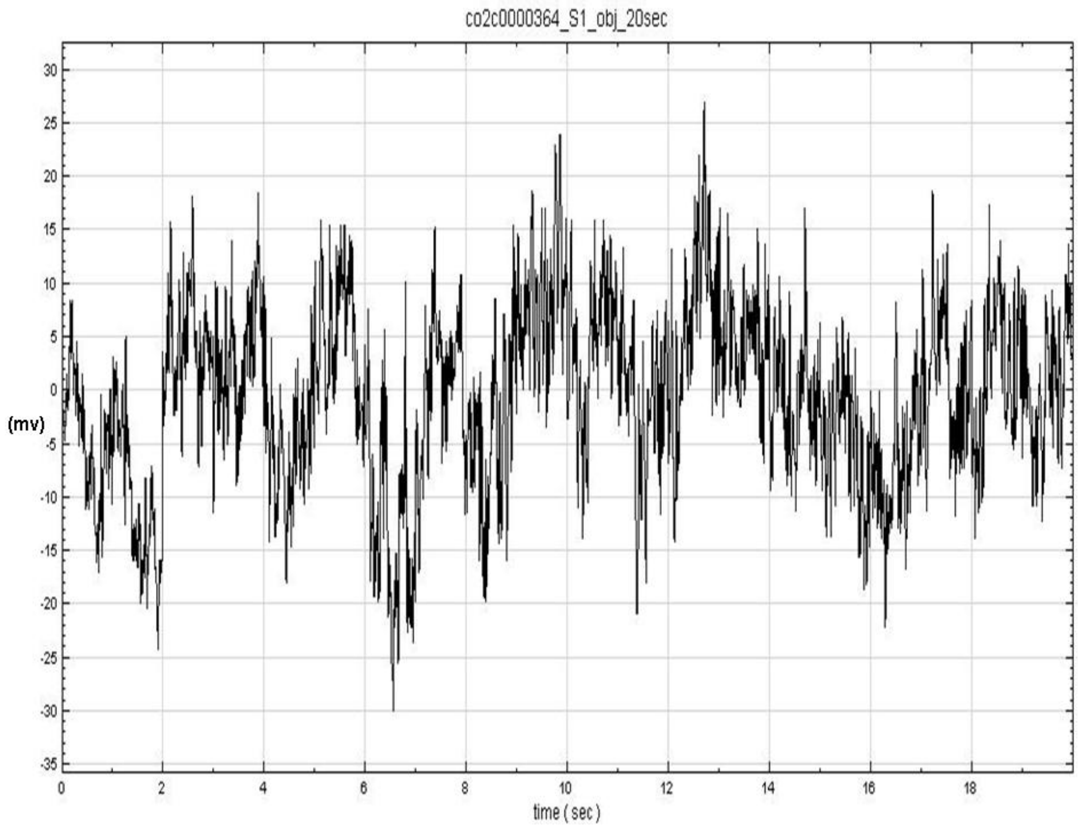

Figure 1 The FP1 EEG signal presented by a normal observer watching a picture.

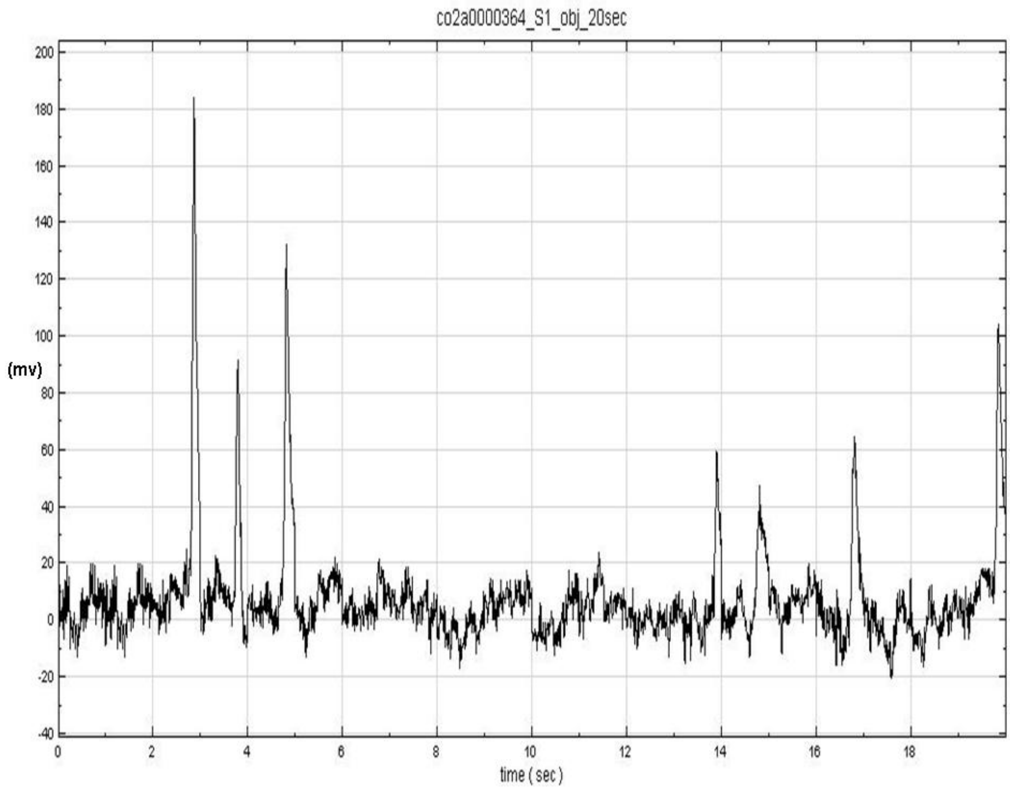

Figure 2 The FP1 EEG signal presented by a member of the alcoholic group.

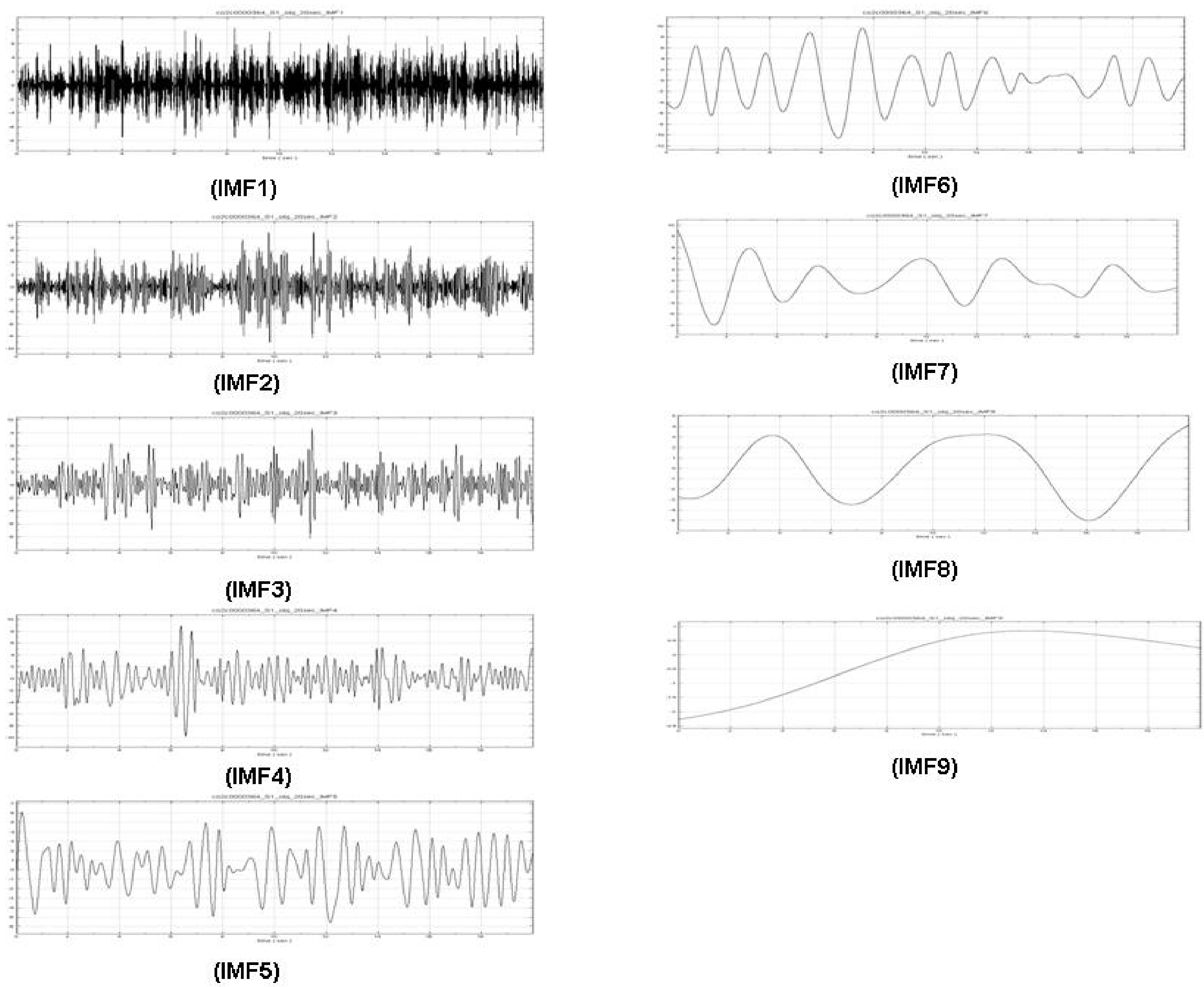

Figure 3 The EEG signal of a normal control person watching a picture (stimulant) and generates 9 IMFs.

picture observers did not appear to indicate significantly larger potentials. The EEG signals of the alcoholic group in the experiment suggested that when they were exposed to the stimulus, brain cells were stimulated and emitted higher voltage potentials. Figure 3 analyzes the EEG signals of a normal control person watching a picture (stimulant) and analysis 9 IMFs. These graphs represent the ingredients composing the EEG signals. These IMFs include EEG frequency, amplitude, and represent on a time axis, the frequency and amplitude of the signals over time, and accompany the increase in analysis frequency, low frequency is obvious. Figure 4 shows the IMFs of an EEG wave presented by an alcoholic group while watching a picture (stimulant). In the first few IMFs, the phenomenon of amplitude decrement is not seen, but the frequency decreases. Some portions with larger amplitudes cannot be seen in the first analysis. Figures 4 obviously indicate the trend of decreasing frequency, decreasing in the same time zone. In addition, present high voltage at 2 to 6 seconds, identical to the time zones of the original EEG display; this is not significant in IMF1. EMD is a kind of movement, through repeated analysis movement seek the useful information: pull the waveform straight gradually during the process, and according to the determining formula to decide when to end the analysis. Figure 5 and 6 show the EEG

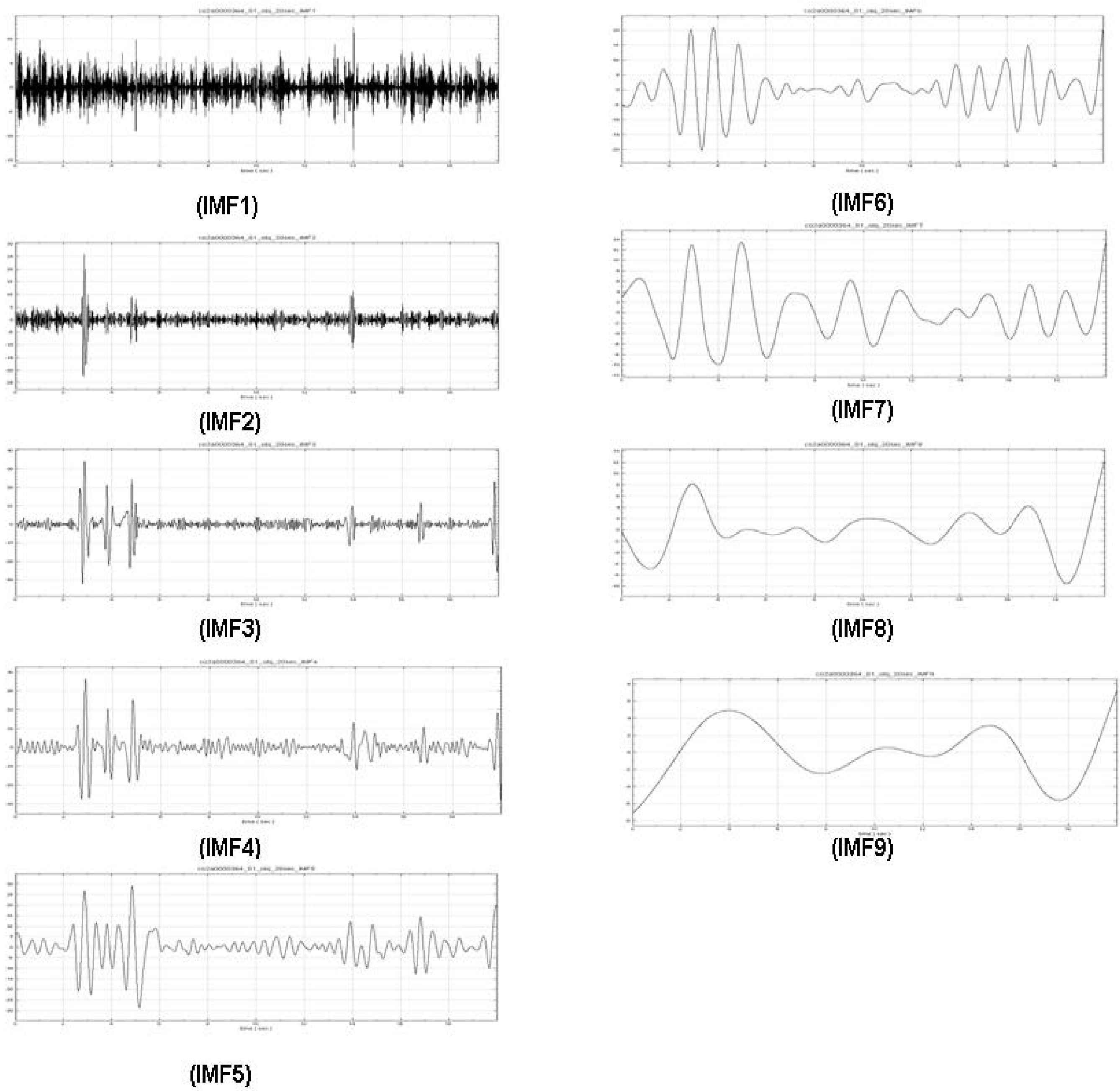

Figure 4 The IMFs of an EEG signal presented by an alcoholic group while watching a picture (stimulant).

signal of a normal control person as well as an alcoholic group while watching a picture (stimulant) and generates 6 IFs, respectively.. Figure 7 and 8 show the Hilbert Marginal frequency graph of a normal and an alcoholic observers while watching a picture. Figure 9 is a Hilbert spectrum graph of a normal observer watching a picture, where higher energy distribution is noted at 0–20 Hz. Figure 10 is a Hilbert spectrum graph of an alcoholic observer while watching a picture. From these figures, we see that the EEG signal characteristics of an alcoholic observer differ with a normal observer on the IMF, IF, Hilbert Marginal frequency, and Hilbert spectrum. We can recognize EEG signal characteristics of IMFs, IFs, Hilbert Marginal frequency, and Hilbert spectrum of an alcoholic and a normal observers to define an alcoholic illness.

4 Conclusion

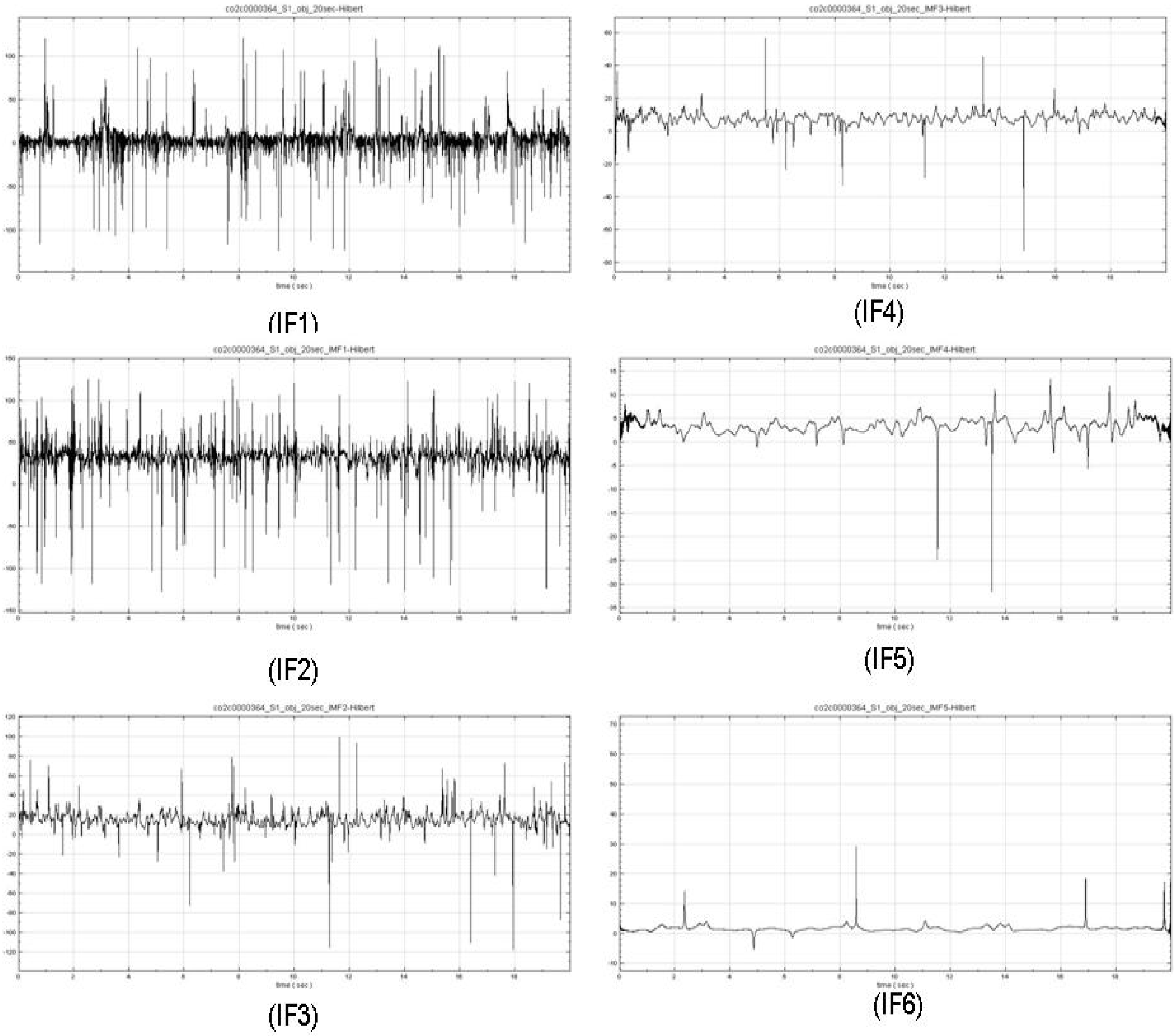

Figure 5 The EEG signal of a normal control person watching a picture (stimulant) and generates 6 IFs.

An HHT-based time frequency analysis scheme was used to evaluate clinical alcoholic EEG signals and present the concept not only on the temporal scale but also by amplitude and frequency. In addition, we discuss that the characteristics of the analysis based on time and frequency domains are superior to other temporal frequency tools, and more information can be obtained from the characteristics expressed by each IMF. The differences of the responses between the alcoholic EEG signal and the normal control EEG signal are discussed in simulation results. From these discussion,We can recognize EEG signal characteristics of IMFs, IFs, Hilbert Marginal frequency, and Hilbert spectrum of an alcoholic and a normal observers to define an alcoholic illness.

Acknowledgement

THE AUTHORS ACKNOWLEDGE THE SUPPORT OF NATIONAL TAIWAN OCEAN UNIVERSITY, CENTER FOR MARINE

BIOSCIENCE AND BIOTECHNOLOGY AND THE CHANG CUNG MEMORIAL HOSPITAL,

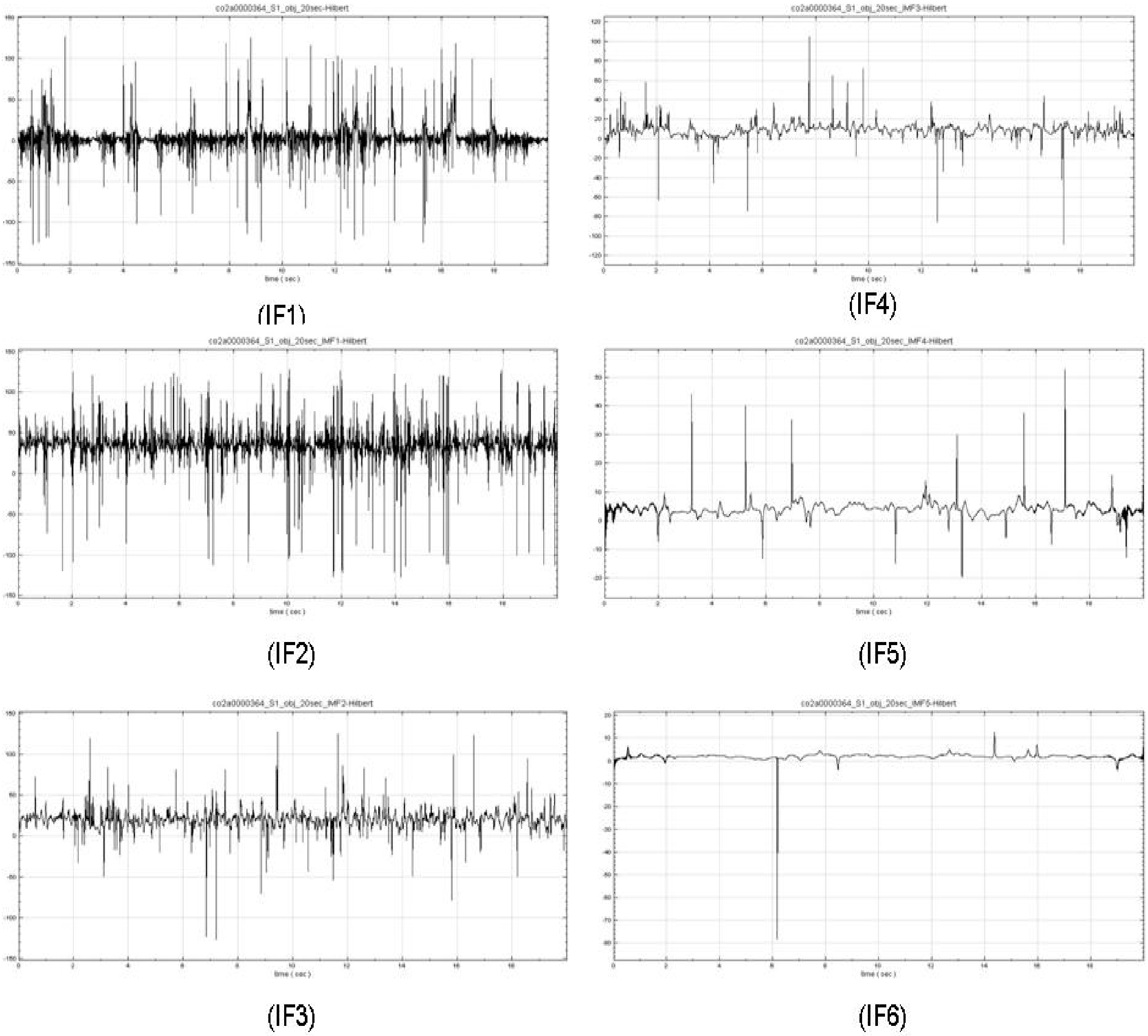

Figure 6 The IFs of an EEG signal presented by an alcoholic group while watching a picture (stimulant).

KEELUNG BRANCH RESEARCH PROJECT AND THE VALUABLE COMMENTS OF THE REVIEWERS.

References

[1] Cohen, L., "*Time-frequency analysis.*" Englewood Clis, NJ: Prentice-Hall, 1995.

[2] Blanco S., Kochen S., Ross O. A., and Salgado P.,"Applying time-frequency analysis to seizure EEG activity," *IEEE Engineering in Medicine and Biology Magazine,* 1997, pp.64-71.

[3] Bigan C. and Woolfson M. S., ,"Time-frequency analysis of short segments of biomedical data," *IEE Proc. Sci. Meas. Technol., 2000,* pp.368-373.

[4] Lin S., Wang H., Ma R., and Zhao H., "Time-Freauency Distribution Based on

Local Frequency and EMD," *Proc. of ICALIP2008*, pp.112-117.

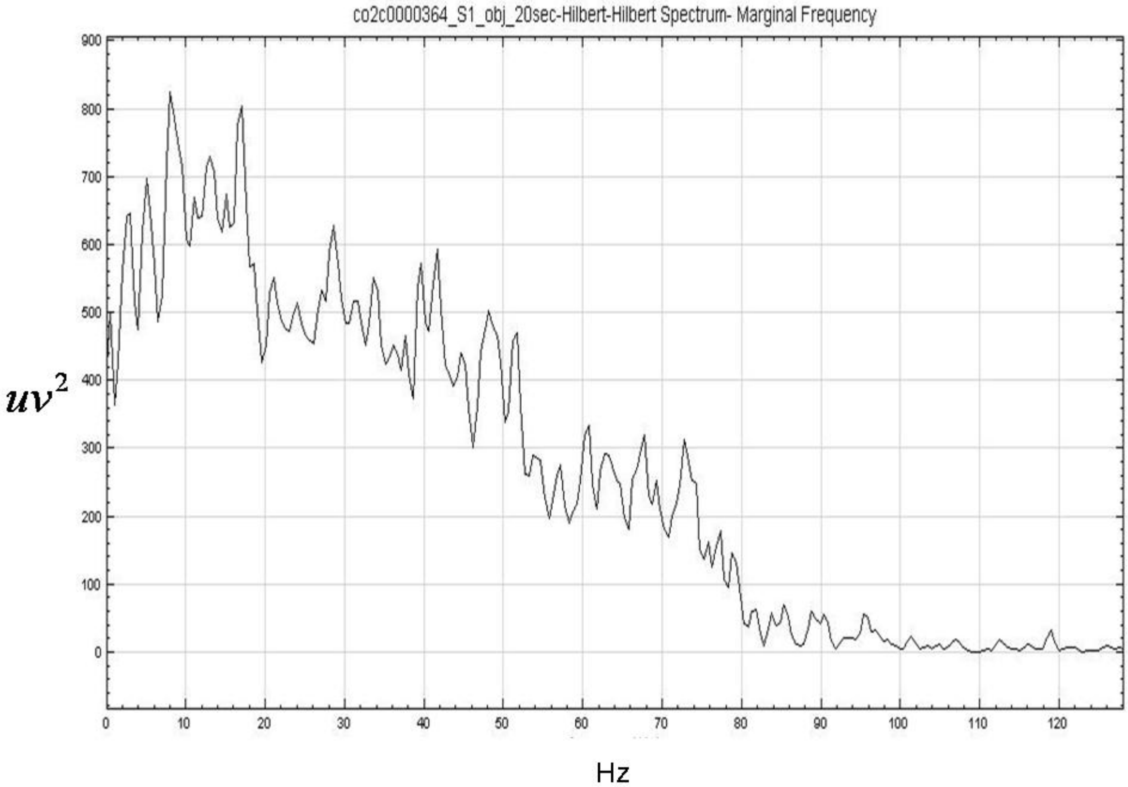

Figure 7 The Hilbert Marginal frequency graph of a normal observer watching a picture.

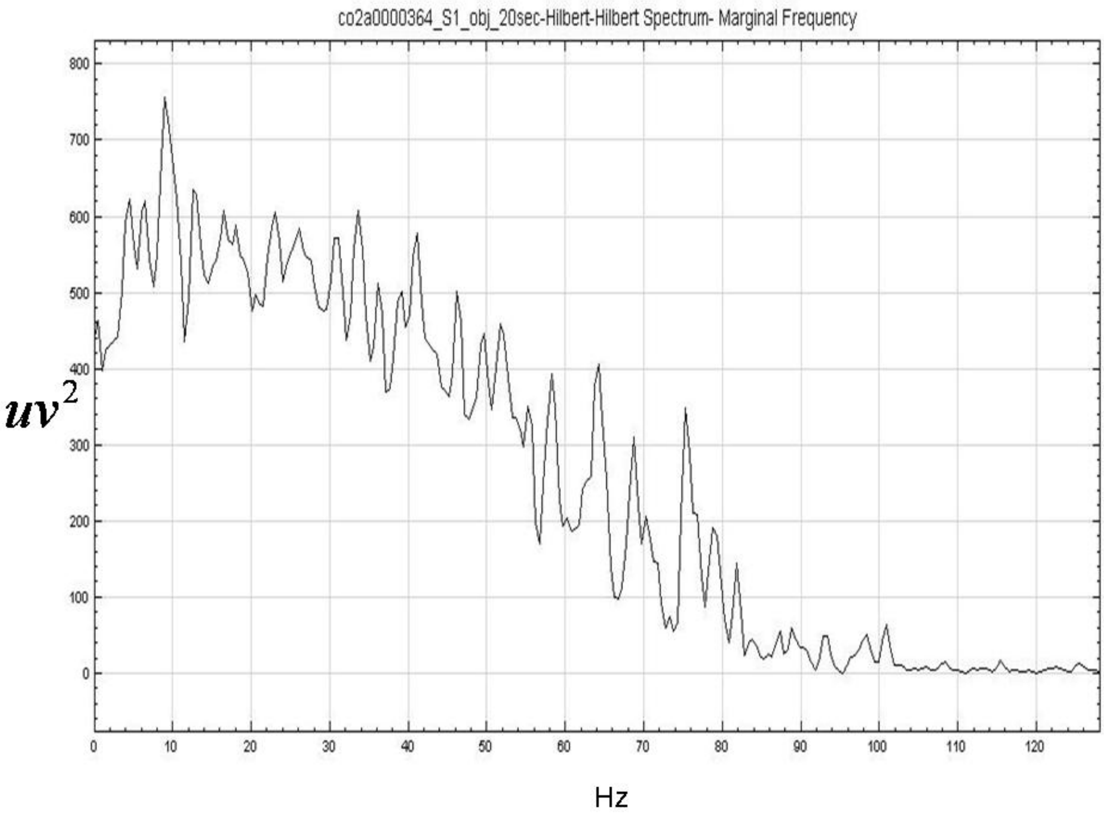

Figure 8 A Hilbert Marginal frequency graph of an alcoholic observer while watching a picture.

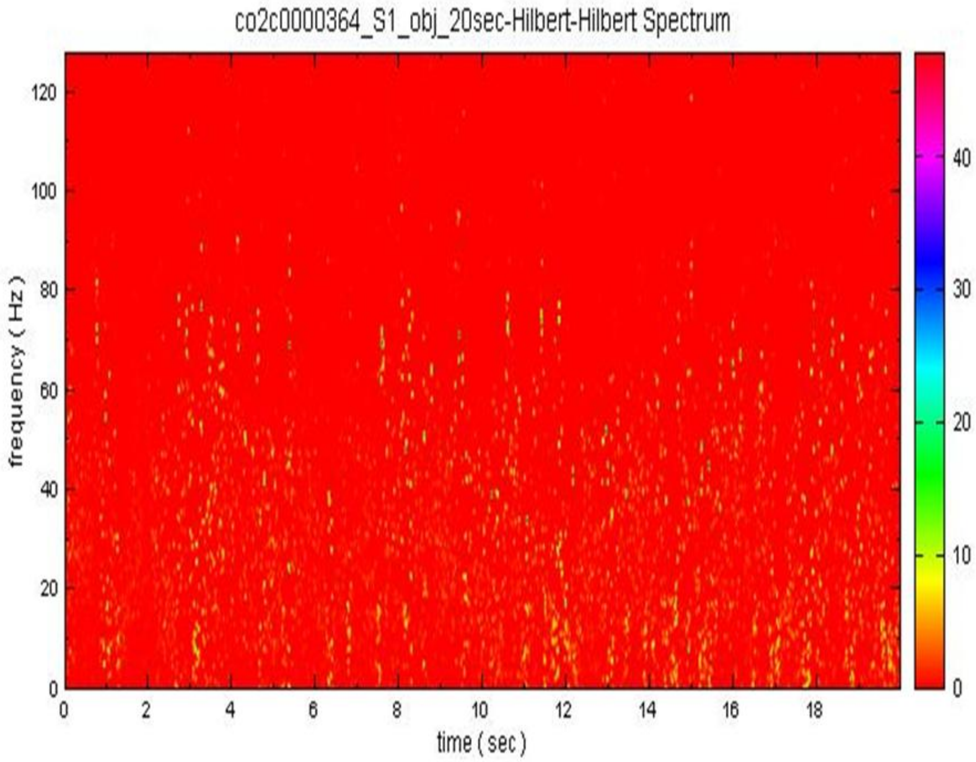

Figure 9 The Hilbert spectrum graph of a normal observer watching a picture.

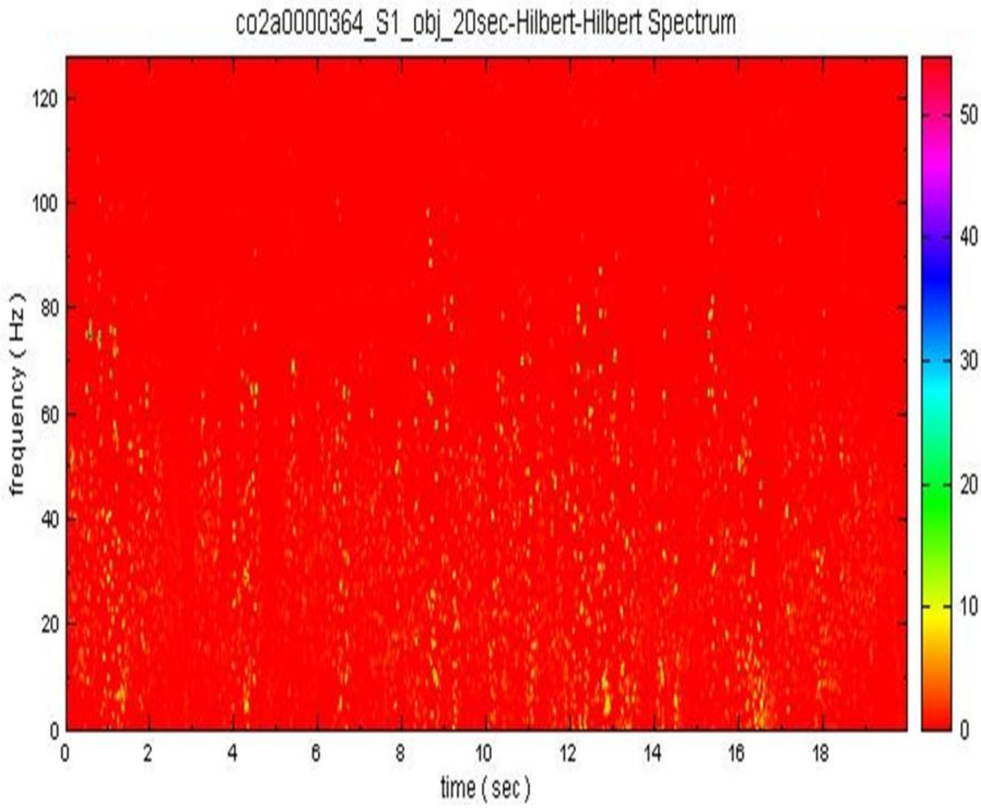

Figure 10 A Hilbert spectrum graph of an alcoholic observer while watching a picture.

[5] Qin S. and Ji Z., "Multi-Resolution Time-Frequency Analysis for Detection of Rhythms of EEG Signals ," *Proc. of IEEE 11th Digital Signal Processing Workshop & IEEE Signal Processing Education Workshop,* 2004, pp.338-341.

[6] Czinege L. and Bloom M. J., "Wavelet-based Spectral Analysis of the Electroencephalogram under Brain Ischemia," *Proc. of 19th International Conference,* 1997, pp.1293-1296.

[7] Kizher S., Flatley T. P., Huang N. E., "On the Hilbert-Huang Transform Data Processing System Development," *Proc. of IEEE Aerospace Conference,* 2004, pp.1961-1979.

[8] Yan R. and Gao X. R.,"Transient Signal Analysis Based on Hilbert-Huang Transform," *Proc. of IMTC2005,* pp.1198-1202.

[9] Kizhner S., Blank K., Flately T., Huang N. E., Petrick D., and Hestnes P.,"On Certain Theoretical Developments Underlying the Hilbert-Huang Transform," *Proc. of IEEE Conference,* 2005, pp.1-14.

[10] Cheng F., Tang B., and He Q. ,"Research on Instantaneous Feature of Nonstationary Signal Based on Hilbert-Hung Transform and Wavelet Packet Decomposition," *Proc. of ICSP2006.*

[11] Sharabaty H., Jammes B., Esteve B., "EEG analysis using HHT: One step toward automatic drowsiness scoring," *Proc. of 22nd CAINA,* 2008, pp.826-831.

[12] Wang Y. L., Lin J. H., and Lin Y. C.,"Automatic Removal Electroencephalogram using Hilbert-Huang Transform," *Proc. of IEEE Conference,* 2008, pp.2138-2141.

[13] Sharabaty H., Martin J., Jammes B., Esteve D. ,"Alpha and Theta Wave Localisation Using Hilbert-Huang Transform: Empirical Study of the Accuracy," *Proc. of IEEE Conference 2006,* pp.1159-1164.

[14] http://kdd.ics.uci.edu/databases/eeg.

[15]http://titan.cog.brown.edu:8080/TarrLab/stimuli/objects/svlo.zip/view.

[16] C. F. Lin, J. Y. Chen, R. H. Shiu, and S. H. Chang, "A Ka Band WCDMA-based LEO Transport Architecture in Mobile Telemedicine," *appear in Telemedicine in the 21st Century, invited book chapter,* edited by Lucia Martinez and Carla Gomez, Nova Science Publishers, Inc, USA, 2008.

[17] C. F. Lin, W. T. Chang, H. W. Lee, and S. I. Hung, "Downlink Power Control in Multi-Code CDMA Mobile Medicine System," *Medical & Biological Engineering & Computing*, vol.44, 2006, pp.437-444.

[18] C. F. Lin and C. Y. Li, "A DS UWB Transmission System for Wireless Telemedicine," *WSEAS Transactions on Systems, July,* 2008, pp.578-588.

[19] C. F. Lin and C. Y. Li, "A Power Assignment mechanism for DS UWB Wireless Telemedicine System with Unequal Error Protection," *WSEAS Books(Proceedings of 12th WSEAS Int. Conf. on System,* Greece 2008), *invited paper*, pp.355-360.

[20] C. F. Lin, and K. T. Chang," A Power Assignment Mechanism in Ka Band OFDM-based Multi-satellites Mobile Telemedicine," *J. of Medical and Biological Engineering,* 28(1), 2008, pp.17-22.

[21] C. F. Lin, C. H. Chung, and J. H. Lin, "A Chaos-based Visual Encryption Mechanism for EEG Clinical Signals," appear in *Medical & Biological Engineering & Computing,*.(OnLine First), 2009.

[22] C. F. Lin and C. S. Chung, "A Chaos Base Visual Encryption Mechanism in ECG Medical Signal, "*Proceedings of World*

Congress on Medical Physics and Biomedical Engineering 2006, pp.2250~2253, Korea.

[23] C. F. Lin and C. H. Chung, "A Fast chaos-based visual encryption mechanism for integrated ECG/EEG medical signals," *WSEAS Books(Proceedings of 12th WSEAS Int. Conf. on System 2008,* Greece), *invited paper*, pp.284-289.

[24] C. F. Lin, and C. H. Chung, "A chaos-based visual encryption mechanism in integrated ECG/EEG medical signals," *Proceedings of IEEE the 10th International Conference on Advanced Communication Technique 2008,* pp. 1903~1907, *Korea.*

[25] C. F. Lin, C. H. Chung, Z. L. Chen, C. J. Song, and Z. X. Wang, "A Chaos-based Unequal Encryption Mechanism in Wireless Telemedicine with Error Decryption, " *WSEAS Transactions on Systems,* 2008, *pp.49-55.*

[26] C. F. Lin, W. T. Chang, and C. Y. Li, "A Chaos-based Visual Encryption Mechanism in JPEG2000 Medical Images," *J. of Medical and Biological Engineering*, 27(3), 2007, pp.144-149.

[27] C. F. Lin, S. W. Yeh, Y. Y. Chien ,T. I. Peng, J. H. Wang ,and S. H. Chang, "A HHT-based Time Frequency Analysis Scheme for Clinical Alcoholic EEG Signals," appear in *WSEAS Books(Proceeding of 9th WSEAS Int. Conf. on Multimedia Systems & Signal Processing 2009, China), invited paper*.

[28] C. Y. Chen, W. K. Wong, C.D. Kuo, Y. T. Liao, M. D. Ke," Wavelet Real Time Monitoring System: A Case Study of the Musical Influence on Electroencephalography," *WSEAS Transactions on Systems*, 2008, *pp.56-62.*