January 31, 2025

AMED (Japan Agency for Medical Research and Development) Supports

International Collaboration

Implementation of wide band EEG in epilepsy care by digital EEG

Lecture:

Wide Band EEG Analysis

Now ready for clinical implementation

Akio IKEDA, MD, PhD, FACNS

Department of Epilepsy, Movement Disorders & Physiology

Kyoto University Graduate School of Medicine

Kyoto, JAPAN

1

31st January 2025
(Friday)

Wide-band EEG from DC shifts to HFO 1

Moderator

Dr. Fitri Octaviana (Dr. Cipto Mangunkusumo Hospital, Indonesia)

Contents

- ✔ Mini lecture from Prof. Ikeda (Kyoto University, Japan) [30 min.]
- ✔ Presentation from Dr. Katsuya Kobayashi (Kyoto University, Japan) [30 – 60 min.]

14th February 2025
(Friday)

Wide-band EEG from DC shifts to HFO 2

Moderator

Dr. Aris Catur Bintoro (Central General Hospital Dr. Kariadi, Indonesia)

Contents

- ✔ Mini lecture from Prof. Ikeda (Kyoto University, Japan) [30 min.]
- ✔ Presentation from Dr. Masao Matsuhashi (Kyoto University, Japan) [30 – 60 min.]

India (New Delhi)	IST	2:30 PM –
Indonesia (Jakarta)	WIB	4:00 PM –
Thailand (Bangkok)	ICT	4:00 PM –
Taiwan (Taipei)	CST	5:00 PM –
Japan (Tokyo)	JST	6:00 PM –

2

Disclosure Form

Company Name	Nature of Affiliation
• Sumitomo Pharma Co • Nihon-Kohden	• Industry-Academia Collaboration Courses • Collaboration study
• UCB Japan • Eli Lilly Japan • RICHO	• Collaboration study
Off-Label Product Usage	
• None	

3

54th Annual congress of JSCN
October 24 ~ 26, 2024, Sapporo, Japan

Sapporo Super EEG
October 24 2024

Wide-band EEG from DC shifts to HFO
(invasive and scalp)
14:00 ～ 15:30

Lecture:

Wide Band EEG Analysis
Now ready for clinical implementation

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Department of Epilepsy, Movement Disorders

4

RESEARCH ARTICLE

Epilepsia

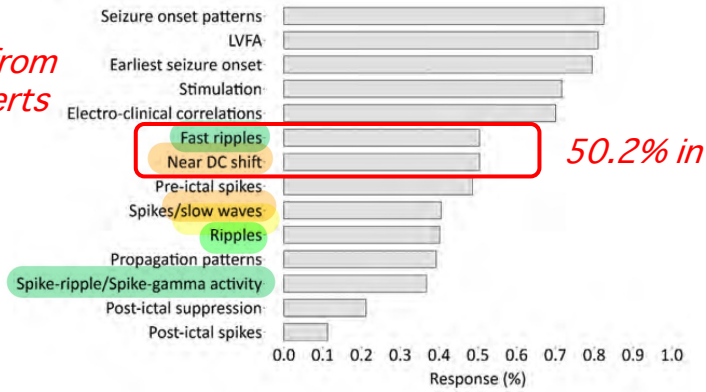
Received: 16 February 2024 | Revised: 11 July 2024 | Accepted: 17 July 2024

Investigating current clinical opinions in stereoelectroencephalography-informed epilepsy surgery

John Thomas[1,2] | Chifaou Abdallah[1] | Zhengchen Cai[1] | Kassem Jaber[1] | Jean Gotman[1] | Sandor Beniczky[3] | Birgit Frauscher[1,2,4]

Out of 14 ictal s-EEG features

(A)



Opinion from 321 experts

50.2% in each

5

Wide-band EEG: a mysterious and very useful technique

1) What is the wide-band EEG?
2) Special machine? Special technique?
3) Is it useful? Is it redundant? Just only research?
4) Useful only in invasive EEG?
5) Is it recorded by scalp-EEG?
6) EEG technologist could analyze?

6

Wide-band EEG: a mysterious and very useful technique

Long introduction

1) active- vs. passive DC shifts
   AMED study in Japan (Multi-institutional study)
   Surgical outcome

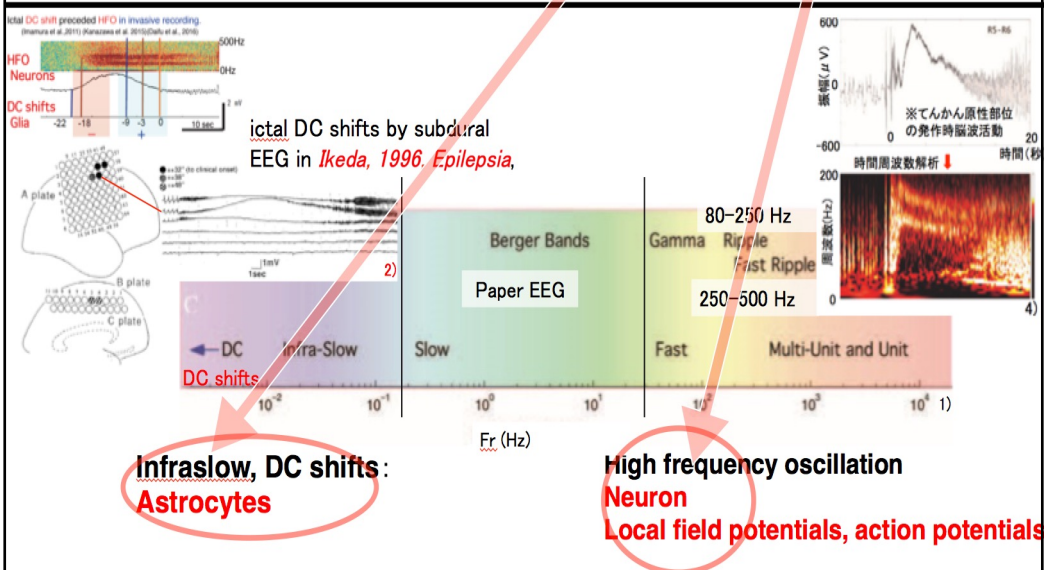
2) 2 types of ictal DC shifts, and pathology

3) Is it recorded by TC 2sec EEG ?

4) Is it recorded by scalp EEG ?

7

Digital wide-band EEG could provide us with both ***infralow/ DC shifts*** and ***high frequency oscillation*** together for invasive EEG as well as scalp EEG as the potential biomarker



1) Worrell, 2008, Brain, 2) Ikeda, 1996, Epilepsia, 3) Kajikawa, 2022, Clin Neurophysiol, 4) Grinenko, 2018, Brain

8

Application of LFF and HFF

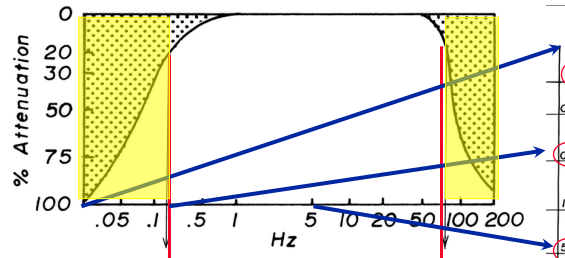


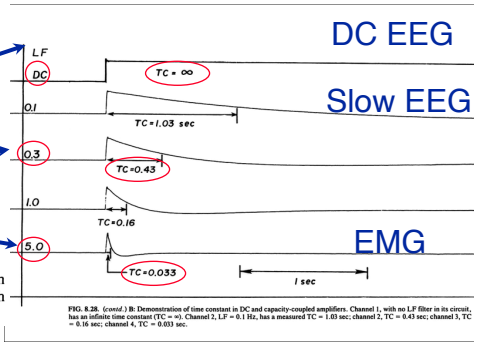
FIG. 8.32. Window based on LF filter 0.3 Hz and HF filter 70 Hz. Based on frequency response curve published by Grass Instrument Company (1973), with permission.

LFF
0.3 Hz
(TC=0.5 s)

HFF
70 Hz

Time constant (TC)

to filter out slow components



TC	x	LFF	=0.16(1/2π)
0.1 sec		1.6 Hz	
1 sec		0.16 Hz	
2 sec		0.08 Hz	
10 sec		0.016 Hz	

9

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10

Epilepsia, 37(7):662–674, 1996
Lippincott–Raven Publishers, Philadelphia

Subdural Recording of Ictal DC Shifts in Neocortical Seizures in Humans

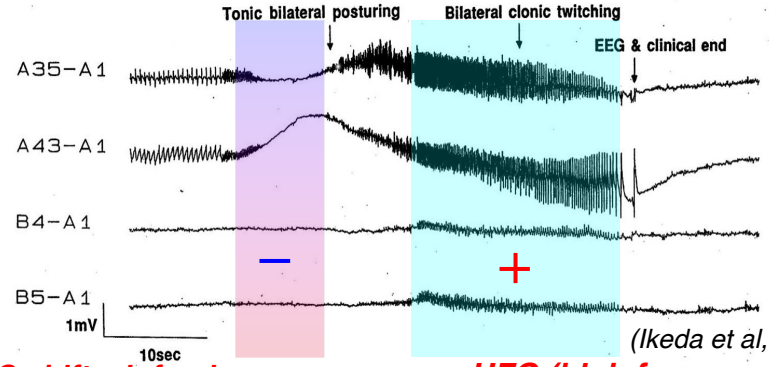
Akio Ikeda, Kiyohito Terada, *Nobuhiro Mikuni, ‡Richard C. Burgess, §Youssef Comair, *Waro Taki, †Toshiaki Hamano, †Jun Kimura, ‡Hans O.Lüders, and Hiroshi Shibasaki

*Departments of Brain Pathophysiology, *Neurosurgery, and †Neurology, Kyoto University School of Medicine, Shogoin, Sakyo-ku, Kyoto, Japan; and Departments of ‡Neurology and §Neurosurgery, The Cleveland Clinic Foundation, Cleveland, Ohio, U.S.A.*

11

Wide-band EEG in clinical（invasive）recording:

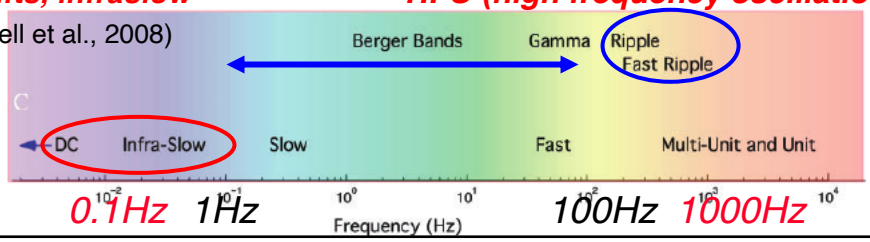
→close to the established tool, but still a research topic



(Ikeda et al, Epilepsia,1996)

DC shifts, infraslow ***HFO (high frequency oscillation)***

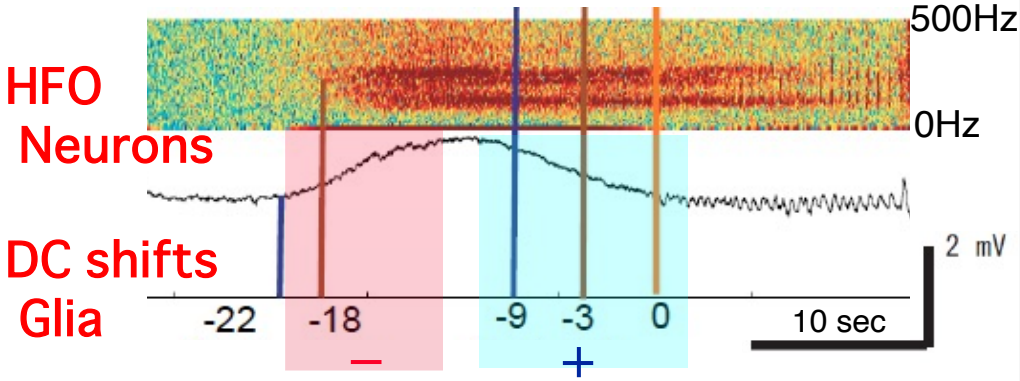
(Worrell et al., 2008)



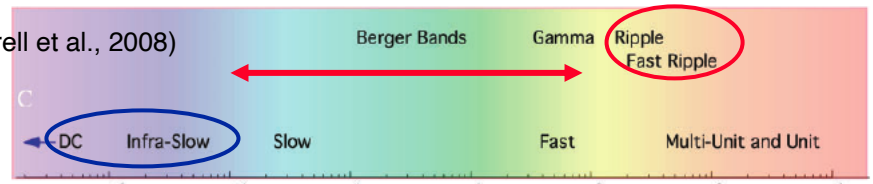
12

Ictal DC shift preceded ictal HFO in invasive recording.

(Imamura et al.,2011) (Kanazawa et al. 2015)(Daifu et al., 2016)



(Worrell et al., 2008)



13

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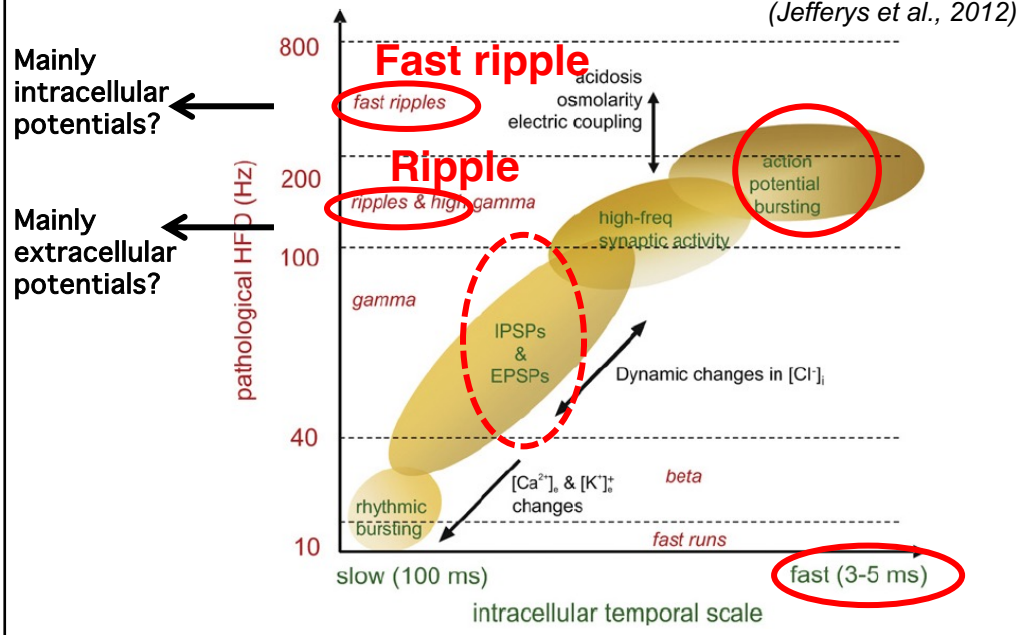
14

Cellular mechanisms underlying pathological HFOs.

(Jefferys et al., 2012)



17

1) Normal HFO (IPSP by interneurons)

2) Pathologic HFO (population spikes from clusters of abnormally bursting of neurons) (Engel et al., 2009)

Interictal HFO vs. ictal HFO

Bursts of neuronal activity mediated by gap junctions (Traubs et al., 2001,2003): synchronous **action potential** firing of a group of principal cells

100-200 Hz : ripple: (normal and epileptic in hipp)

250-500 Hz : fast ripple (only epileptic in hipp)

HFO located in a more restricted area as compared with conventional EEG

（Jirsch et al. 2006, Ochi et al.,2007）

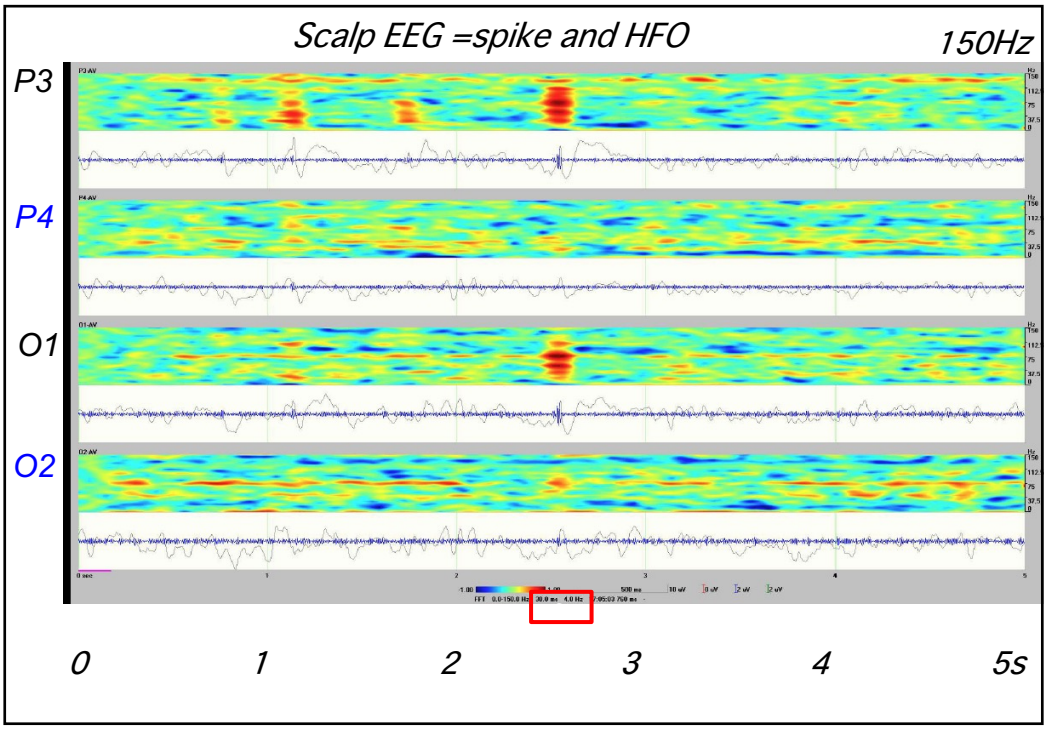
18

A comparison to epilepsy surgery outcome

	Retrospective study	Prospective study
Interictal HFO	•Jacobs J et al. Ann Neurol. 2010;67:209-220 •Akiyama T et al. Epilepsia 2011;52:1802–1811 • Van Klink NEC et al. Ann Neurol. 2017; 81: 664-676 others **Effective**	•Jacobs J et al. Neurology. 2018;91(11):e1040-e1052. 5 institutes •Zweiphenning W et al. Lancet Neurol. 2022; 21(11): 982–993 3 institutes **Non-effective**
Wide-band EEG (Ictal DC shifts ictal HFO)	• Nakatani M et al. Brain Commun. 2022; 4(5) : fcac222. doi: 10.1093/braincomms/fcac222 5 institutes in Japan **Effective**	SDG(subdural grid) → SEEG **Not yet**

(a table made by Prof. T Maehara, Tokyo, Japan)

19

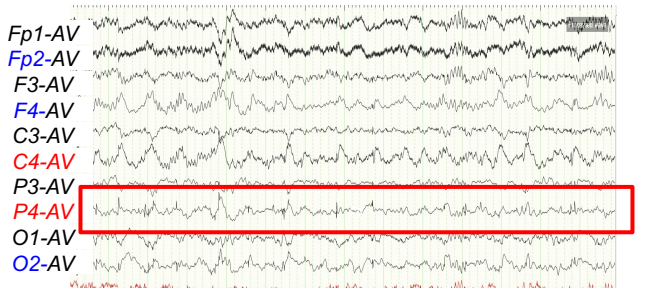


20

Scalp EEG: interictal HFO (high frequency oscillation)

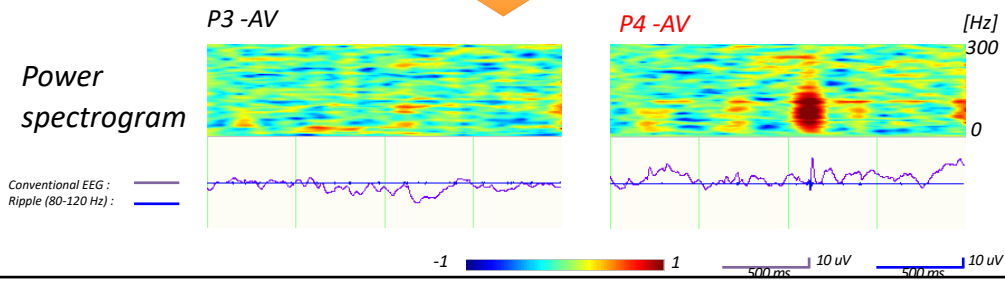
:28yo man
:Rt parietal lobe epilepsy
: FCD Type 2A

Sampling rate: 1000 Hz
Band pass filter: 0.016 – 300 Hz
Notch filter: 60 Hz
FFT size: 250 pts
AV montage



Wide range time frequency analysis (interictal、HFO)

Power spectrogram



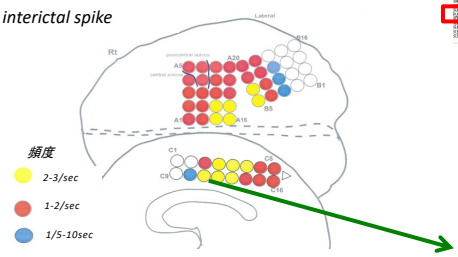
21

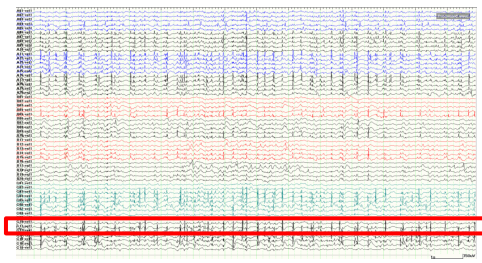
Subdural EEG: interictal HFO (high frequency oscillation)

:28yo man
:Rt parietal lobe epilepsy
: FCD Type 2A

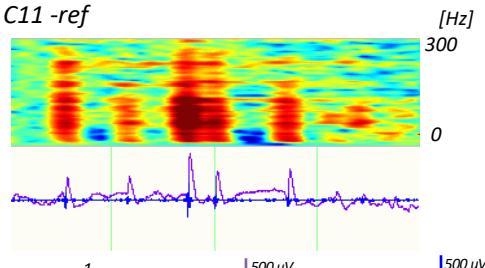
Subdural electrode location

interictal spike





Wide range time frequency analysis (interictal、HFO)



Sampling rate: 1000 Hz
Band pass filter: 0.016 – 300 Hz
FFT size:250 pts
referential montage

22

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23

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(a table made by Prof. T Maehara, Tokyo, Japan)

24

Terminology: Ictal DC (direct current) shifts

Also described as very slow, infra-slow, steady, ~~baseline shifts~~

Recorded by

DC amplifier	DC shifts
AC (alternative current) amplifier	Slow shits

long time constant, i.e. 10 sec→***2 sec for scalp***

small low frequency filter (LFF) i.e., 0.016Hz→***0.08Hz***

25

Both ictal DC shifts & HFO recording

invasive recording

subdural electrodes

sampling rate: 2000Hz

LFF: 0.016Hz (=TC of 10sec)

HFF: 600Hz

(Imamura et al, 2011; Kanazawa, et al., 2014)

26

Recording condition of ictal DC shifts

1) DC amplifier
   AC amplifier with opened LFF: 0.016 or 0.05 Hz
   (time constant of 5 or 10 sec)

2) huge input impedance of amplifier (>50 MΩ) →***200 MΩ***

3) *Non-polarized (reversible) electrodes*
   Ag/AgCl for scalp recording (not for invasive)
   platinum for subdural recording →***may not a big deal by 2)***

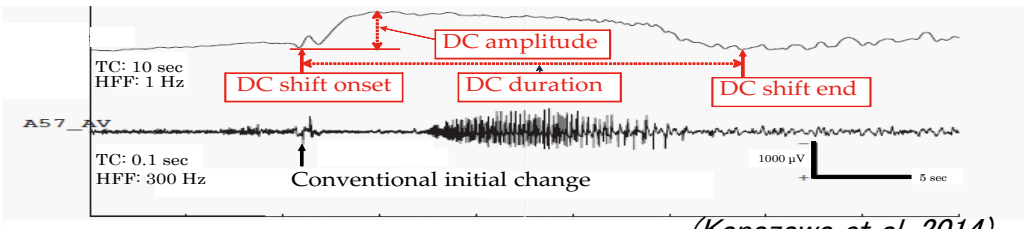
4) *Large recording surface, i.e., subdural electrodes rather than depth electrodes* →***not a big deal by 2)***

Practical (operational) definition of ictal DC/ slow shifts (Ikeda et al.,1999)

1) Not detected by LFF of 0.1Hz, but only detected by opened LFF (=becomes clearer with longer time constant, i.e., by changing from 0.1 to 10)

2) Usually negative (or infrequently positive) in polarity, >3sec in duration, peak to peak amplitude along the entire waveform of at least 200microV, preferably >1mV.

3) Reproducible in waveforms, duration and location.



(Kanazawa et al, 2014)

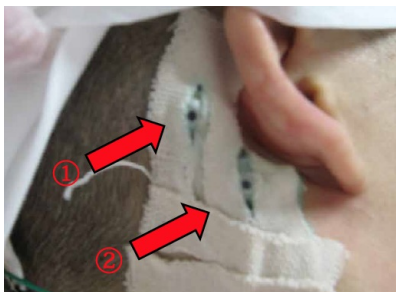
Recording condition

1) LFF is kept open for continuous monitoring.

2) System reference electrode should not be epileptically irritative and the metal should be identical to that of recording electrode, i.e., platinum scalp electrodes,

3) Scalp electrodes made by platinum are placed as the ① system reference and ② ground electrode.
Electrode impedence of the two is kept below <5kohm

(Ikeda et al., 1999; Kanazawa et al,2014)



29

Display condition

1) Referential montage is recommended as display montage

2) System reference electrode should not be epileptically irritative and the metal should be identical to that of recording electrode, i.e., platinum scalp electrodes,

3) System reference electrode and display reference electrode are initially identical in order to avoid any mis-reformating, i.e., mastoid process skin electrodes.

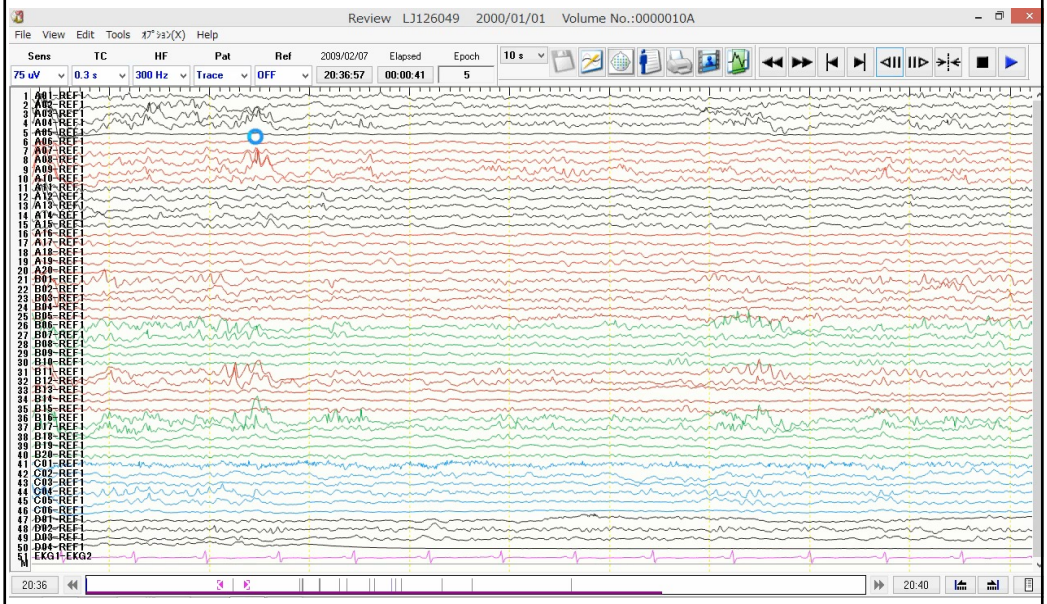
4) Once initial, display reference electrode was not suitable (i.e., motion artifacts, etc.), it could be changed to 1) non-irritative subdural electrode or 2) averaged electrode activity.

(Ikeda et al., 1999; Kanazawa et al, 2014)

30

Recording condition: Sampling rate=2kHz, TC=10s, HFF=300Hz

display condition changed: from TC0.3 to 10、time window=20,30,60sec, 2m, 3m,



31

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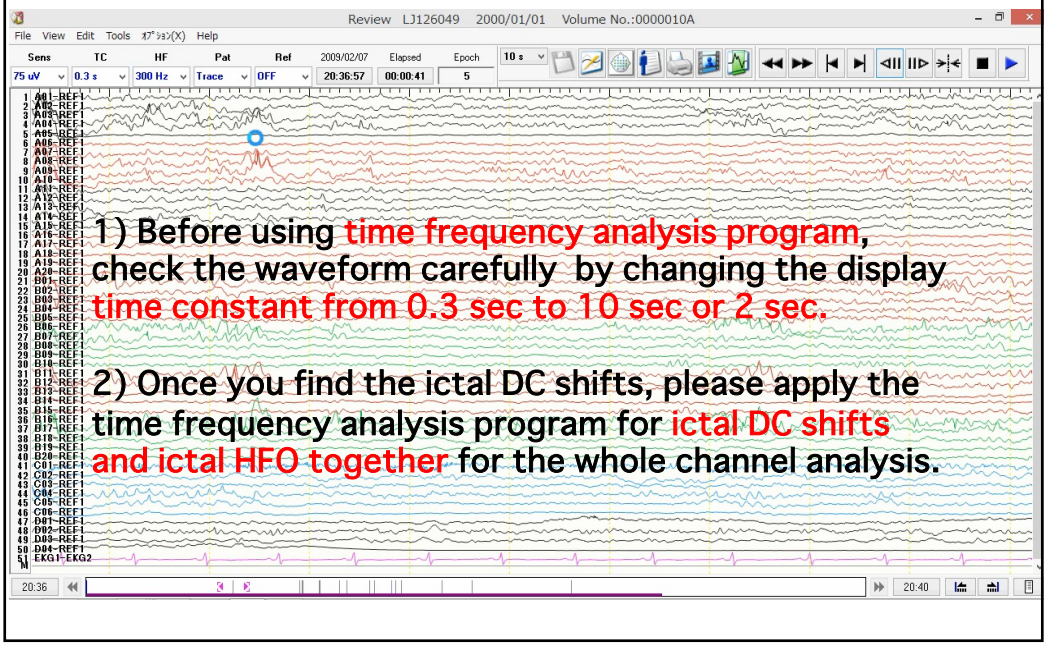
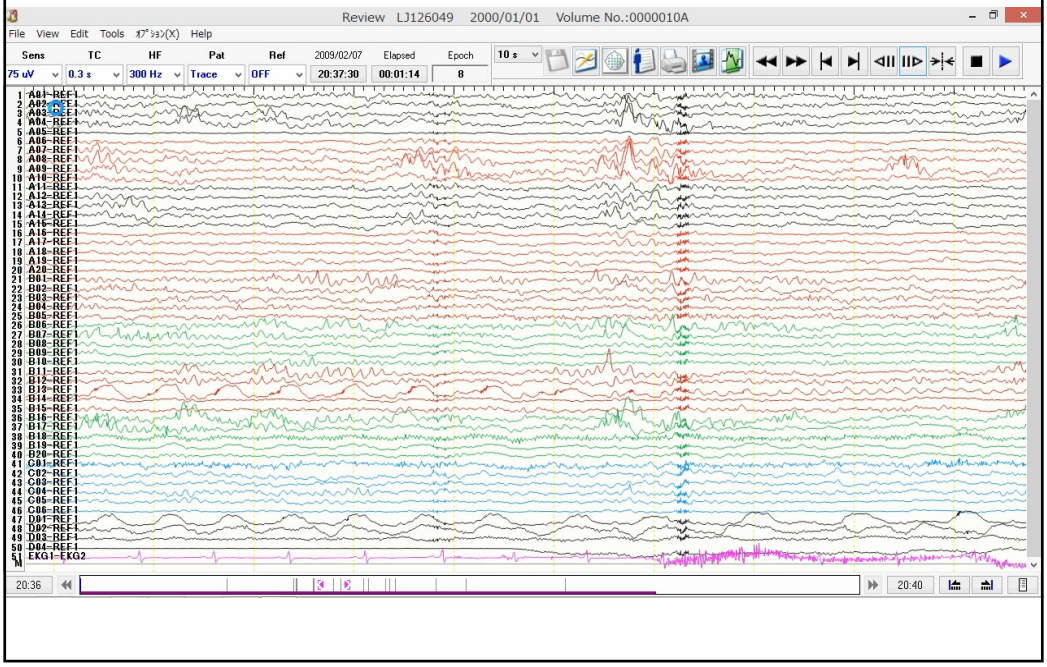


32

Time frequency analysis on the EEG review station (+-60sec)

Collaboration with Nihon Kohden（HFO up to 600Hz and DC shifts shown together in the review station)



33

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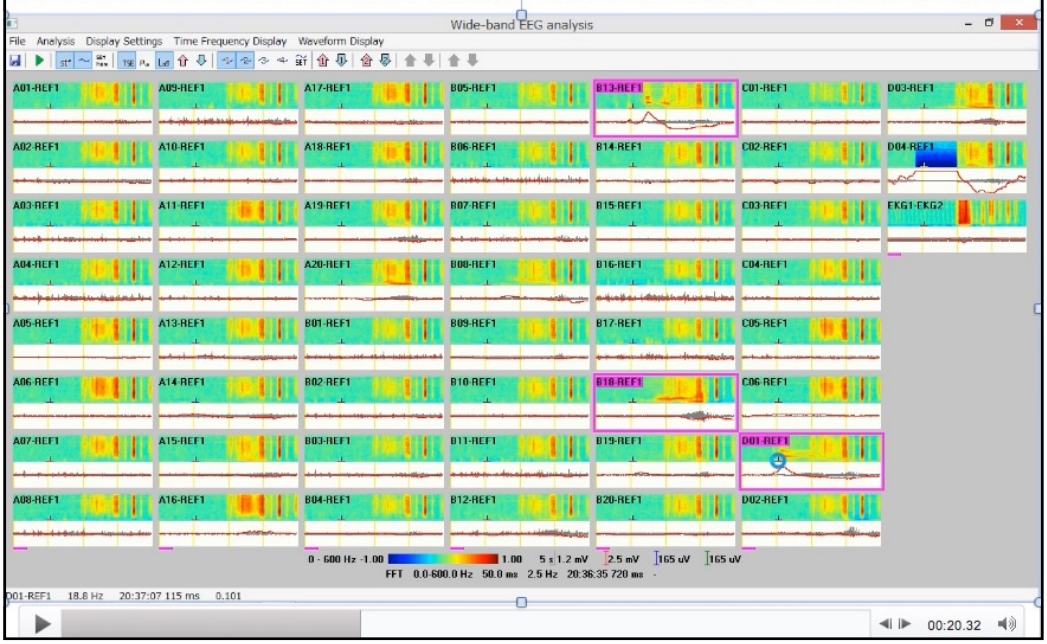

34

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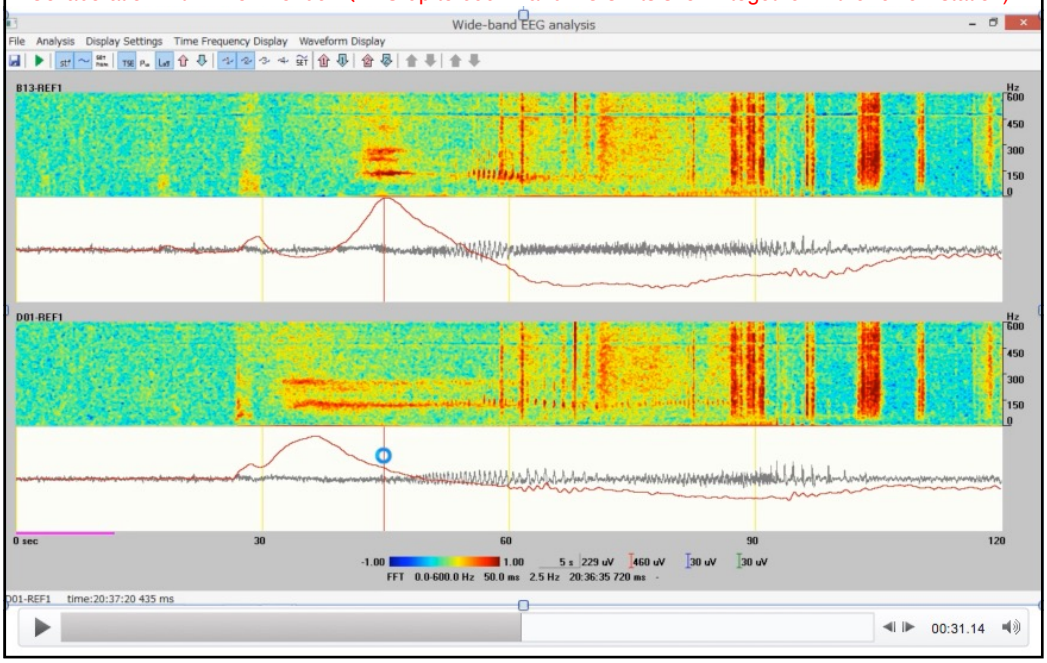
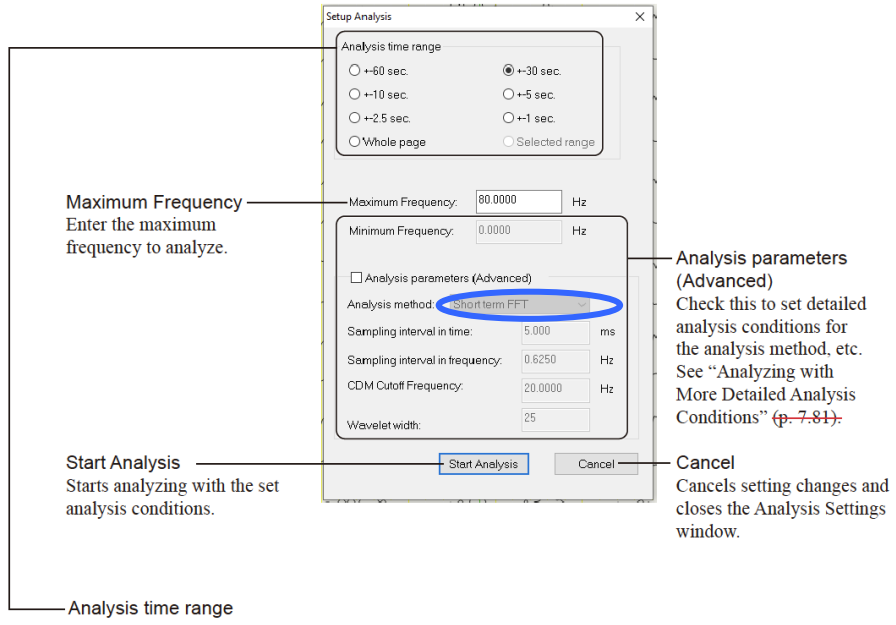
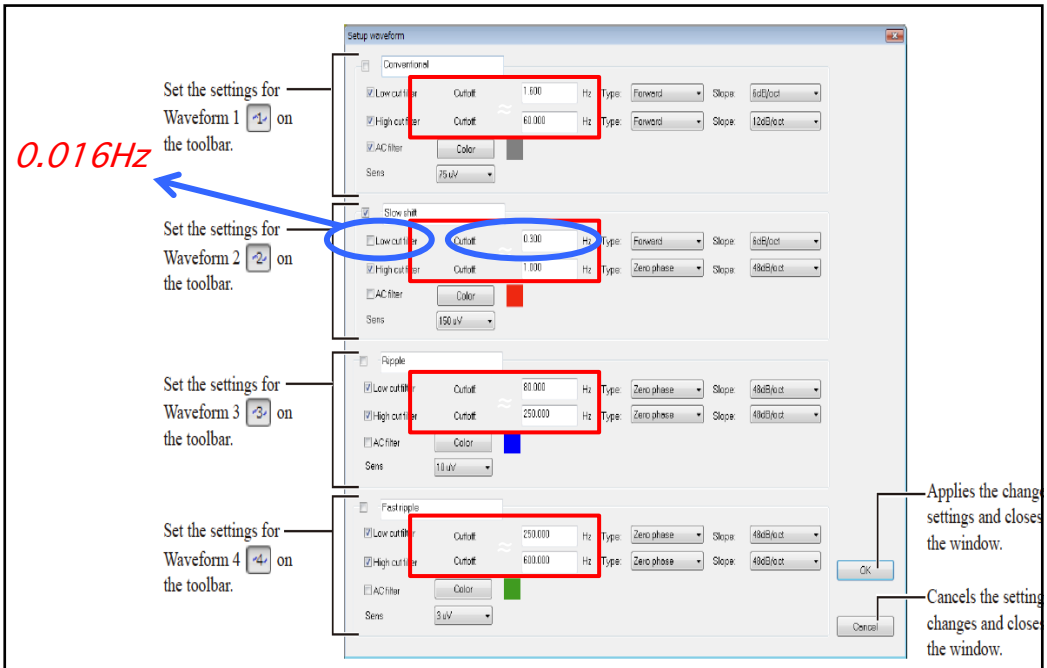


35



(Wide-band EEG Analysis: quick reference by Nihon Kohden、p5)

36



(Wide-band EEG Analysis: quick reference by Nihon Kohden、p12)

37

0.016Hz

Item	Setting Range	Initial Setting			
		Waveform 1	Waveform 2	Waveform 3	Waveform 4
Waveform Name	Up to 64 alphanumeric characters	Conventional	Slow shift	Ripple	Fast ripple
Low cut filter	ON/OFF	ON	OFF	ON	ON
Cutoff frequency	—	1.6 Hz	0.3 Hz	80.0 Hz	250.0 Hz
Type	Forward*1/Zero phase*2	Forward	Zero phase	Zero phase	Zero phase
Slope	—	6 dB/oct	48 dB/oct	48 dB/oct	48 dB/oct
High cut filter	ON/OFF	ON	ON	ON	ON
Cutoff frequency	—	60 Hz	1.0 Hz	250.0 Hz	600.0 Hz
Type	Forward*1/Zero phase*2	Forward	Zero phase	Zero phase	Zero phase
Slope*3	—	12 dB/oct	48 dB/oct	48 dB/oct	48 dB/oct
AC filter	ON/OFF	ON	OFF	ON	ON
Waveform color	—	Gray	Red	Blue	Green
Sens	—	75μV	150μV	10μV	10μV

(Wide-band EEG Analysis: quick reference by Nihon Kohden、p13)

38

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