



Walter E. Washington Convention Center
November 15, 2023

Abstract Title: A signal processing method applied to the electroencephalogram as inspired by the concept of striatal beat frequency is used to form a basis from which to separate frequency specific beat patterns is developed through the exploitation of single-periods of single-frequencies and correlation coefficient.

Session Title: Computational Tools for Physiological Data Analysis

Presentation Number: NANO92.09

by

James P. LaRue

Signal Processing Scientist

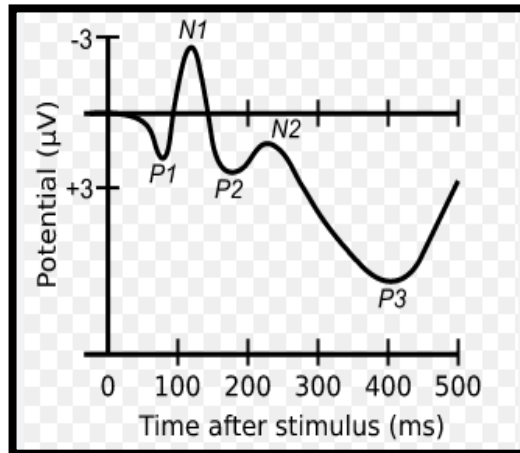
JADCO Signals: Joining Analog and Digital Communication Signals

ABSTRACT

This paper proposes a method for time-domain analysis of an electroencephalogram (EEG) using the theory of interval timing and Striatal Beat Frequency (SBF) first developed by Matell & Meck back in the year 2000. We first form a bank of single-period single-frequency (SPSF) sinusoids where the number of points making up each SPSF sinusoid is commensurate with the EEG device sampling rate. Then we choose a common starting reference point in the EEG where we center each individual SPSF and record each separate correlation coefficient (CC) in a column of a matrix where each row corresponds to a separate SPSF. As the bank of SPSFs is moved to the next point in time in the EEG another set of CCs is calculated and recorded in the next column of the matrix. The process is continued until the end of the EEG. In this way we avoid the inevitable drawback of non-periodic chopping within a windowed DFT and that of non-normalized outputs and frequency spreading of the Geophysics-derived Wavelet constructs. We may think of this process as a slow Fourier transform that is organized and normalized at each instance. From this matrix of CCs we can now place intuitive thresholds in order to visualize the on-off pattern of our modeled SBFs across each individual row in time and may act as a common standardized basis that is easily reproducible because of its bare-bones construction and more importantly, current algorithms will no longer be constrained the usual (delta, theta, beta, and gamma bands) bands or to a particular wavelet shape, and in the case of estimating phase locking values the SPSF approach may mitigate the problems associated with applying the Hilbert transform function inside a band-passed filtered window of EEG. Using epileptic seizure data, sampled at 256 Hz, from the ChB MIT scalp EEG database and Temple University Seizure Detection Corpus we compared the outputs from the DFT, Wavelet, and SPSF methods and found that the SPSF method identified low amplitude frequency components that were overlooked by the Wavelet method and it outperformed the DFT by clearly identifying on-off sequences of specific rows of frequency components, in particular at the 2, 7, and 15 Hz rows for this particular patient, whereas the DFT was smeared across the spectral output. There was evidence that the SPSF could draw attention to early-onset detection of non-convulsive status epilepticus (NCSE). We will show additional results of the SPSF method from an EEG recording from this 63 year old male author at a sampling rate of 19.2 KHz which is free from 60 Hz contamination.

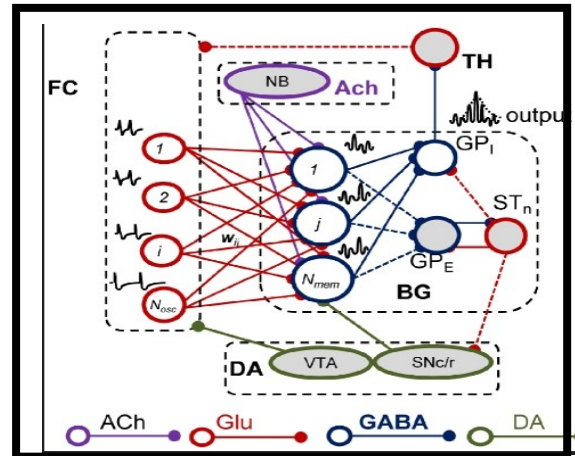
Today's discussion: Measuring ERPs through conceptual SBFs and realizable SPSFs

Event-related Potential (ERP)



Striatal Beat Frequency (SBF) concept

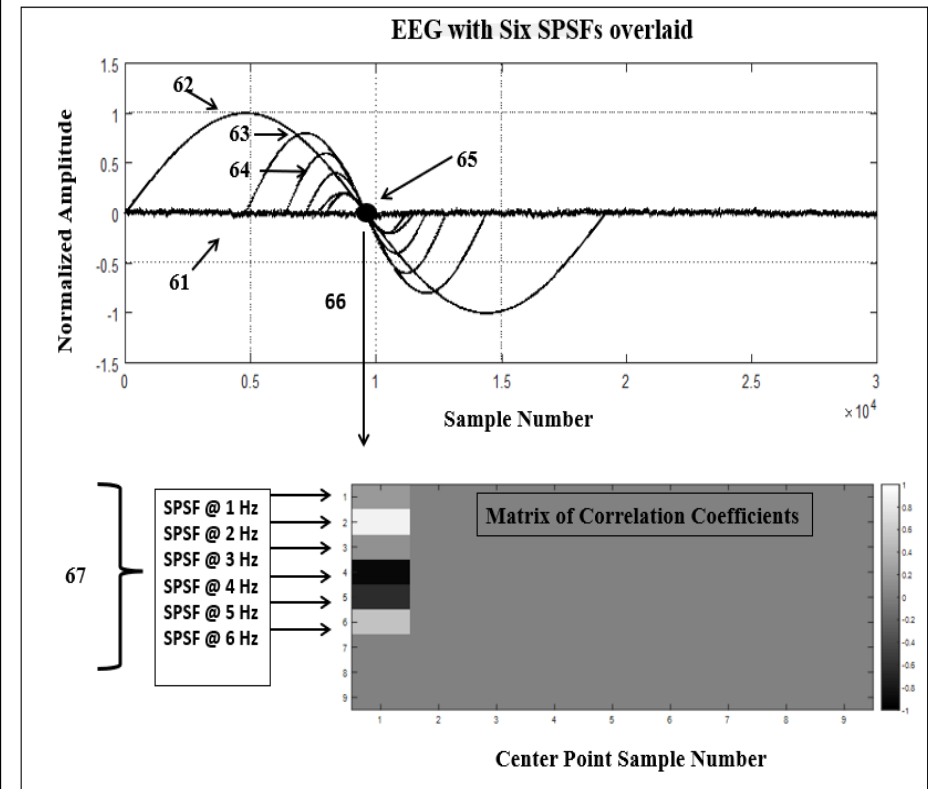
Duke: Matell, Meck, and Buhusi



How our solution to realizing (ERP) SBFs was approached:

- “No” to black box Time Stamping
- “No” to window FFT smearing
- “No” to Geophysics-based Gaussian spread Wavelet suites
- “Yes” to using a bank Single-Period Single-Frequency sinusoids which wasn’t possible/practical back in 2004.

SPSF is a point by point searching method that uses Single-Periods of Single-Frequencies to characterize SBFs in an EEG



Analyzing EEG with Single-Period Single-Frequency Sinusoids

Patent No.: US 11,179,085 B2

Date of Patent: Nov. 23, 2021

Potential use cases for EEGs

Post Traumatic Stress Disorder (PTSD) \$232.2 billion annual costs as of 2018

(<https://www.apa.org/monitor/2023/01/staggering-ptsd-costs>)

- \$232.2 billion annual costs as of 2018, \$26K/\$18K per military/civilian
- Occurs more frequently among active-duty military than civilians, but less among veterans than civilians
- • **PTSD split 66.4% share of women, 33.6% of men**
- What are anticipated savings? (lives and money)

Early-onset detection of nonconvulsive status epilepticus (NCSE)

- • **SBF oscillations are short lived**, only lasting for one or two oscillations before rest and re-bursting.
- Determine level of validity, specificity, and accuracy the SBF method can detect NCSE or seizures at large.
- Determine to what level the patient is more responsive to earlier intervention with medicine.
- Determine to what level the neurocritical care unit is able to administer care to the patient in a timely-manner

The efficacy of this uniquely fundamental approach offers:

- • **Earlier personalized detection** and characterization which may lead to lowering staggering treatment cost
- Lowering suicide rates and improving quality of life for family members.
- A positive way for Veterans to see their own improvements

The drawback with windowing: it's blind to WHERE the window should be placed

I am a Signal Processor, taught by Dr. George Ioup out of University of New Orleans. We focused our attention on the Fourier Transform and in particular the reality of using the 'discrete' and time limited (windowed) DFT.

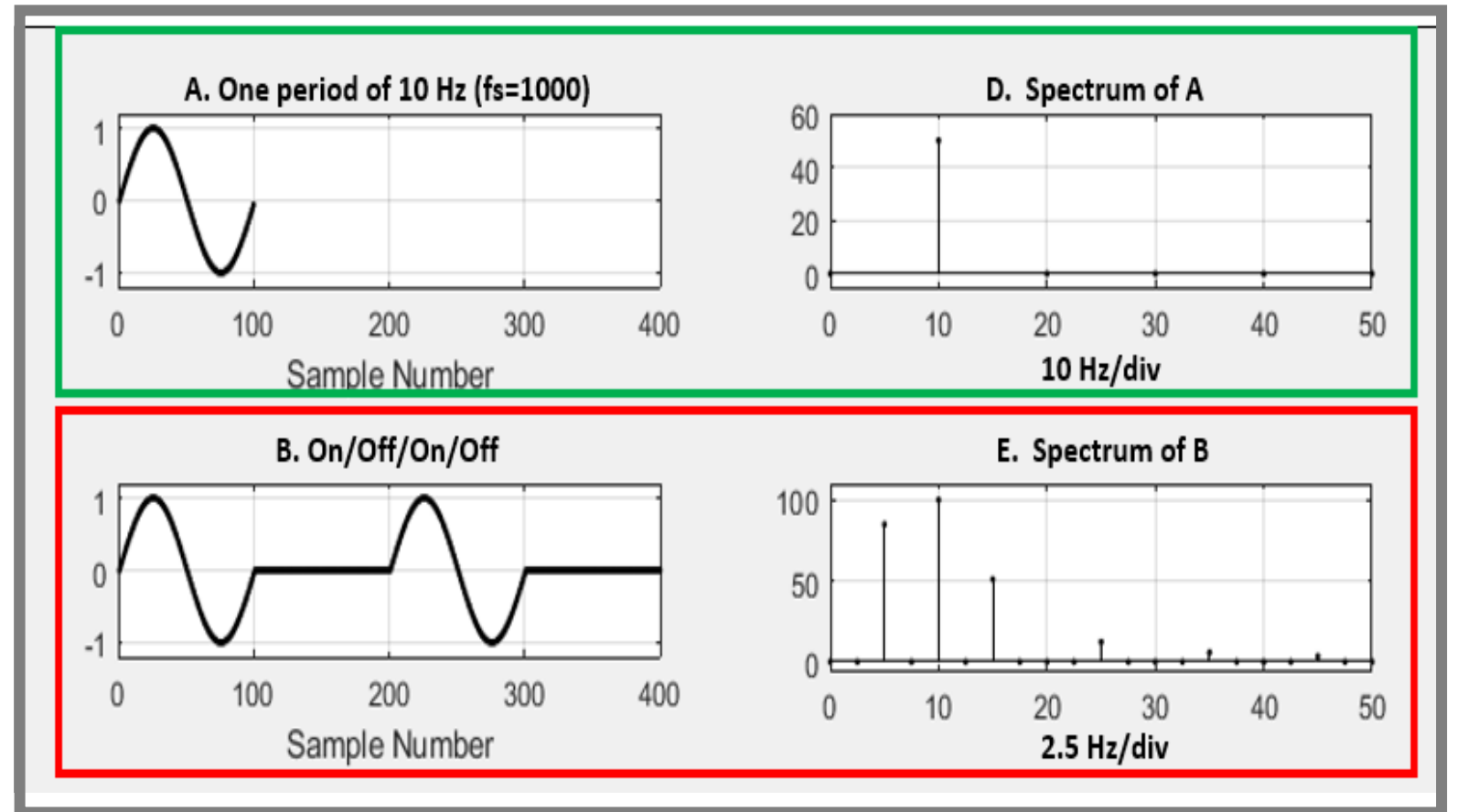
One can apply the DFT to anything, sinusoidal or not, and get a return. But with windows there is chopping. The method in my patent does not chop.

A shows one period of a sinusoid and **D** shows the (perfect) spectrum.

B windows two sinusoids but they are separated by a resting period.

E The spectrum says it sees a 5, 10, and 15 Hz signal.

From my research into multipath with Dr. George Smith, NRL Stennis, Come to realize that **B/E** is a comb).



EEG data acquired courtesy of through G-Tec's Albany, NY Lab and a Data "Basis" each from MIT and Temple U

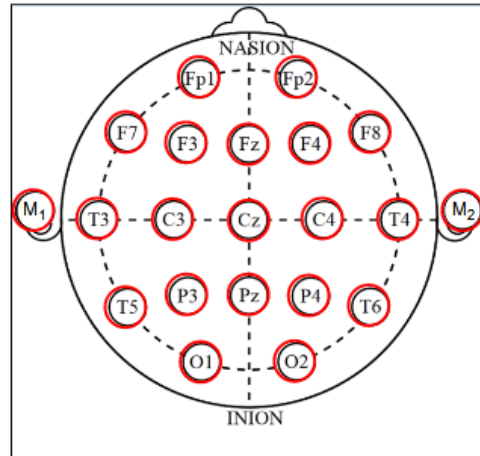
g.tec medical engineering GmbH

Out of Austria, office in Albany, NY
Guger had me meet up with Fan Cao,
Tech/Sales Rep Fan Cao,
he recorded my own EEG,
just three electrodes, for 30 seconds,
sample rates: 512 Hz, 2KHz, 19KHz.

Noise FREE of 60 Hz (yes, it's possible)

This data was basis for the patent,
and yes,
it took a long time to calculate
the SPSF matrix of CCs.

10/20 Montage



Channel 1: FP1-F7	Channel 13: FP2-F8
Channel 2: F7-T7	Channel 14: F8-T8
Channel 3: T7-P7	Channel 15: T8-P8
Channel 4: P7-O1	Channel 16: P8-O2
Channel 5: FP1-F3	Channel 17: FZ-CZ
Channel 6: F3-C3	Channel 18: CZ-PZ
Channel 7: C3-P3	Channel 19: P7-T7
Channel 8: P3-O1	Channel 20: T7-FT9
Channel 9: FP2-F4	Channel 21: FT9-FT10
Channel 10: F4-C4	Channel 22: FT10-T8
Channel 11: C4-P4	Channel 23: T8-P8
Channel 12: P4-O2	Channel 24: ECG

Chb-mit-scalp-eeG-database (seizure)

File Name: chb08_21.edf, fs=256 Hz

Start	Stop	Label
1679	1781	seiz
3782	3898	seiz

Temple University (Picone)

Seizure Detection Corpus

01_tcp_ar, aaaaaarq_s017_t001

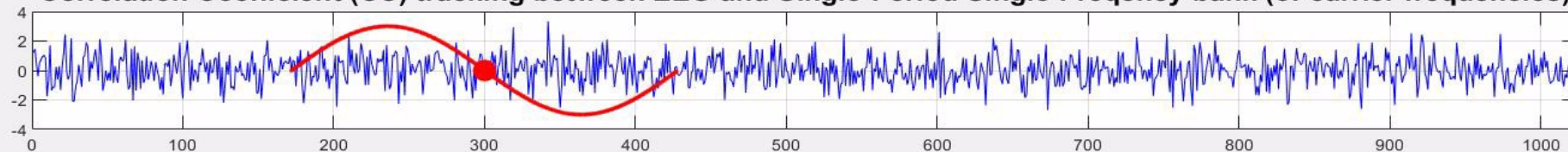
2014_06_29

601.00 secs, fs=256

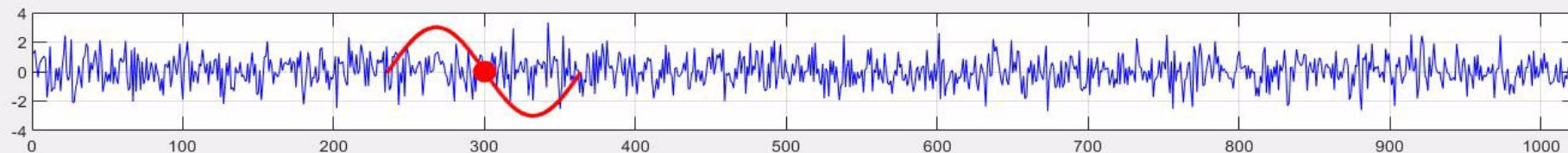
Start	Stop	Label
179.02	198.98	seiz
289.00	311.98	seiz
327.02	337.83	seiz
365.03	385.00	seiz
436.01	448.05	seiz

Correlation Coefficient (CC) tracking between EEG and Single-Period Single-Frequency bank (of carrier frequencies)

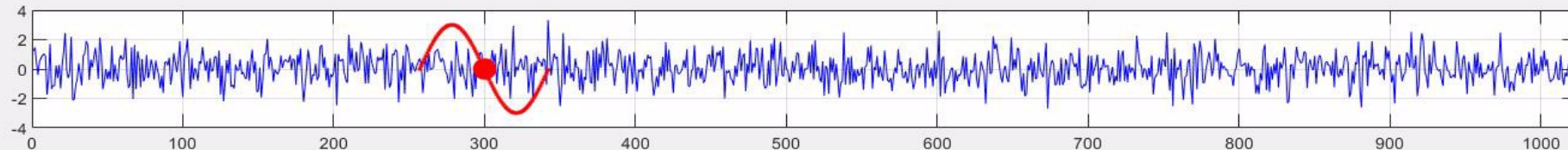
SPSF 1 Hz



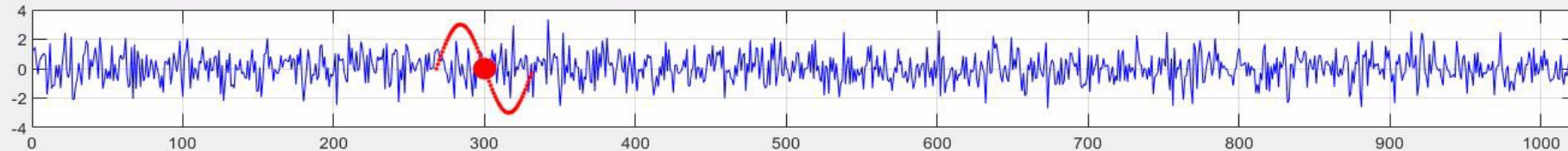
SPSF 2 Hz



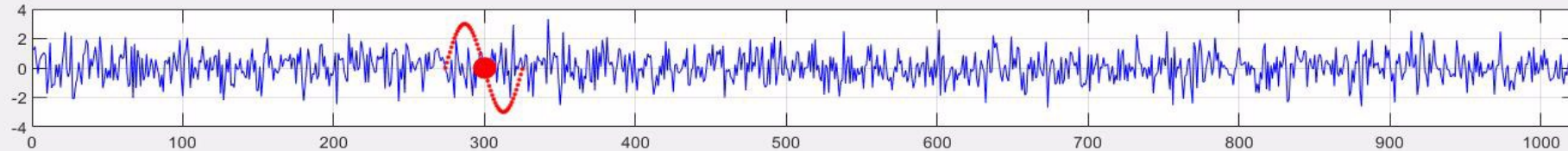
SPSF 3 Hz



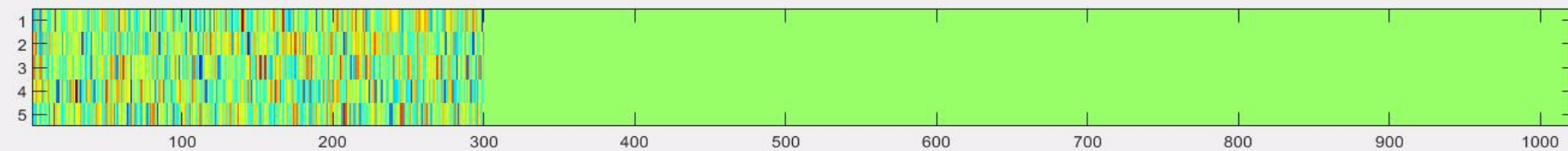
SPSF 4 Hz



SPSF 5 Hz



SPSF CCs

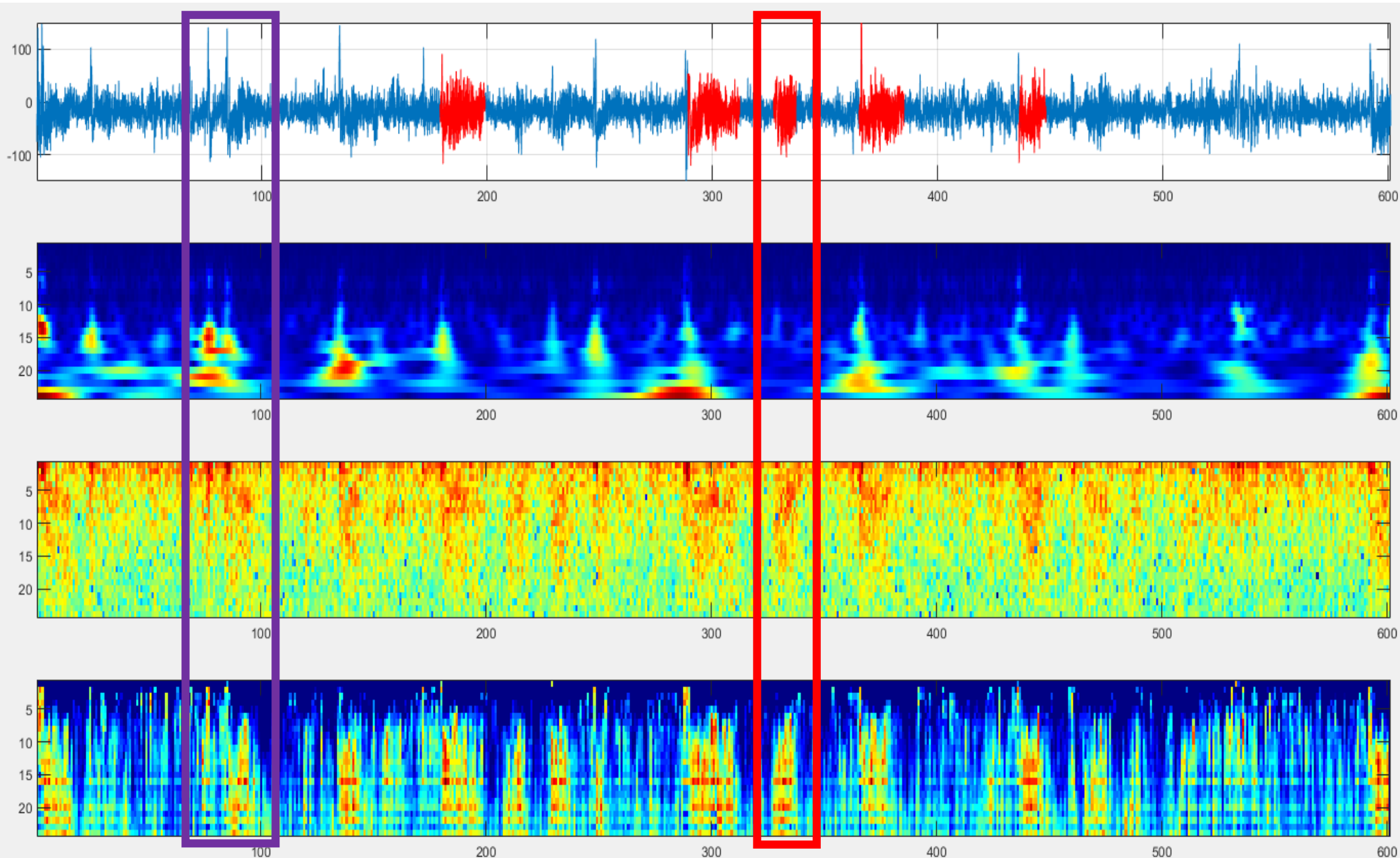


Sample Number tracking Time Sample Rate = 256 Hz SHowing 1024 samples == 4 seconds

(Naïve) EEG analysis with Window FFT, Wavelets, SPSFs

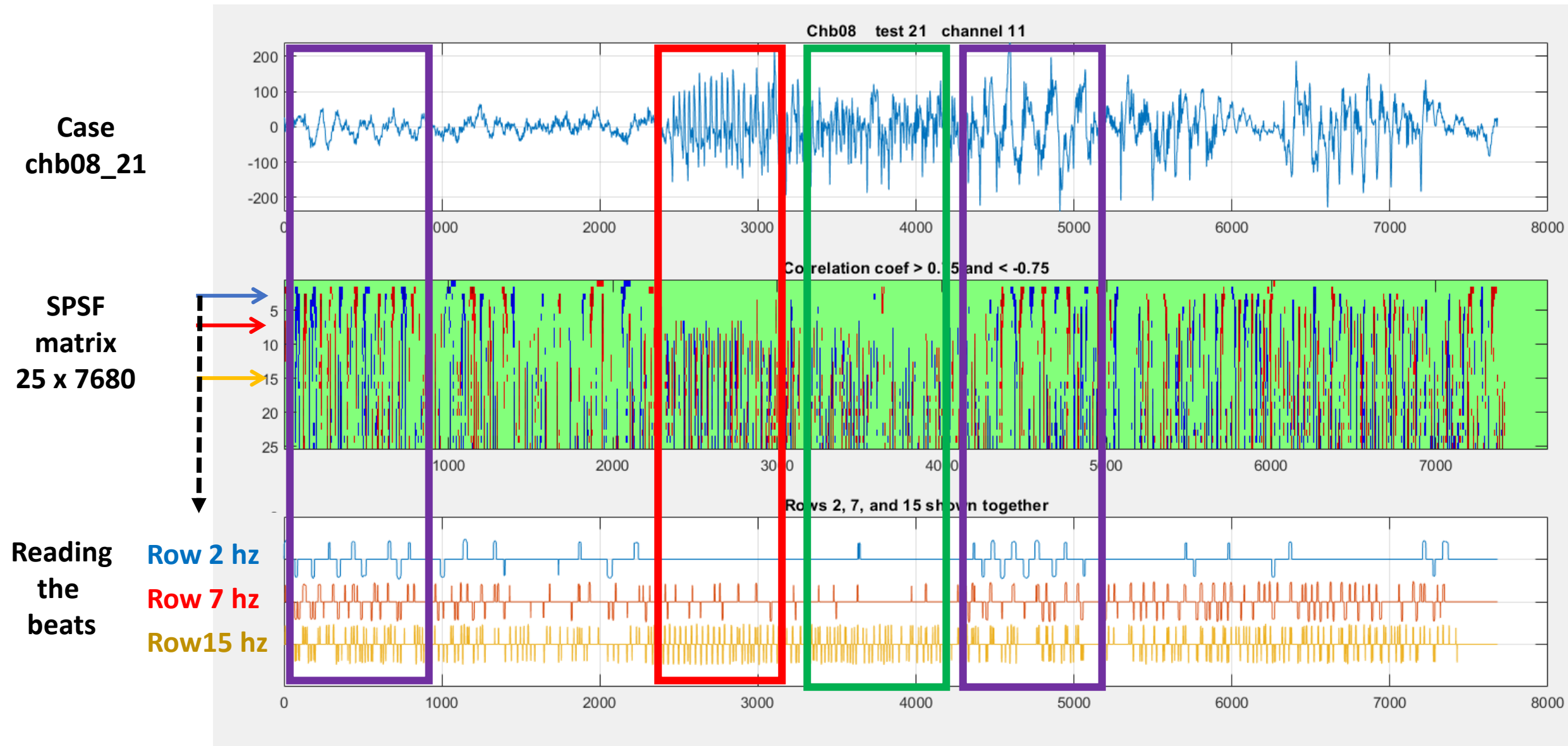
(Temple data set)

aaaaaarq
s017_t001
256 Hz



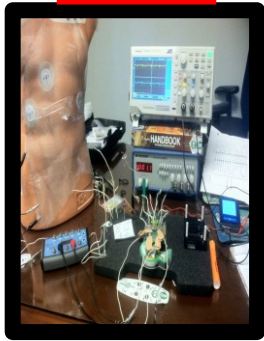
Clinician reading an epileptic seizure (like an ECG tape)

(MIT EEG data base)

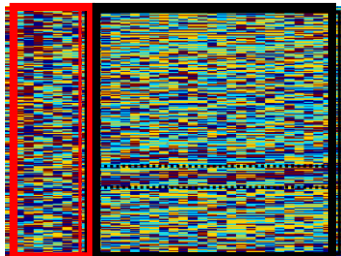


Bridging the RAINNEs with the Joint Proximity Association Templates (JPAT)

Heart



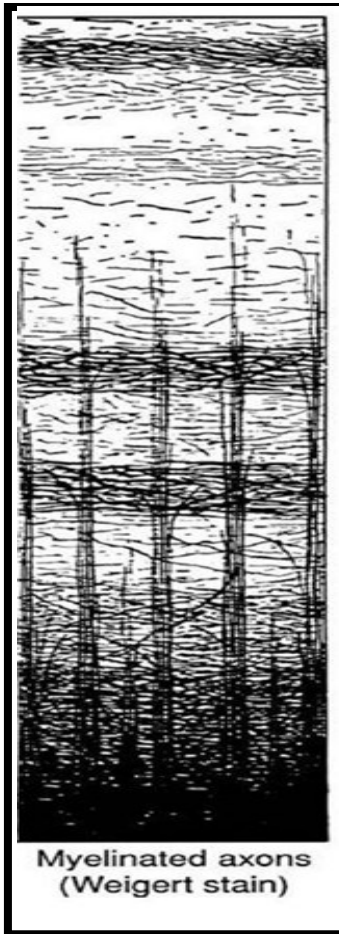
NC002695 Genomes 'talk'



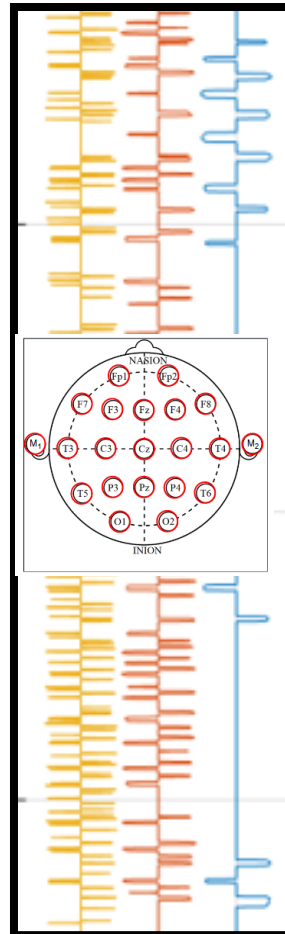
*inspired by
John Butler
DNA Forensics*

“Real” neurons produce beat patterns
Analyzing EEG with Single-Period Single-Frequency Sinusoids

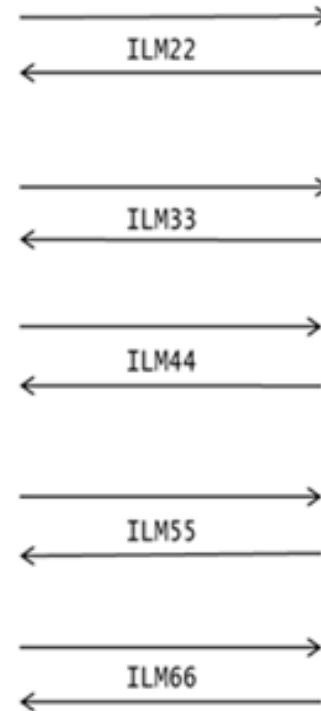
Patent No.: US 11,179,085 B2
Date of Patent: Nov. 23, 2021



Myelinated axons
(Weigert stain)



Bridging Real2Imag

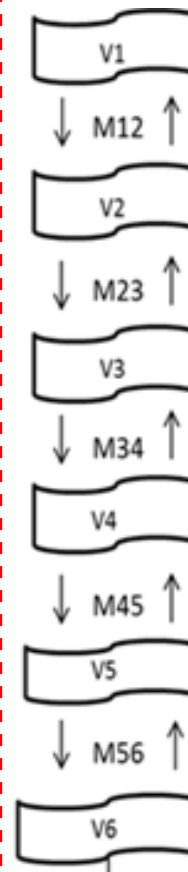


“Imaginary” neurons produce classes
(sight, sound, touch, taste, smell)

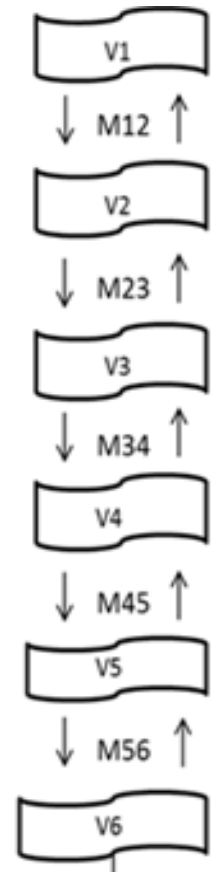
JPAT for Neural Networks
Patent No.: US 10,242,313 B2
Date of Patent: Mar. 26, 2019

Left Eye

Bridging CNN2CNN



Right Eye



Thank you to SPIE 2023 and SfN 2023 and...

David Furford – Signal Processing Technician and Technical Trainer (do Nyquist*5)
Richard Tutwiler – Penn State – ICA input
Catalin Buhusi – Medical University of South Carolina – EEG Time Stamps
Yuriy Pershin – University of South Carolina – Memristors (Leon Chua-Berkeley)
George Ioup – University of New Orleans, Physics-based Signal Processing
George Smith – NRL Stennis – Blind Deconvolution and ‘that Null Space’
Graciela Chichilnisky – Columbia University – Black Swan Theory
Edmond Rusjan – SUNYIT – Fourier Transform, Matrix Methods, and Sequences
Adam Bojanczyk – Cornell – Extended Matrix Methods
Randall King – Avondale Shipyards – RF Waveform Analysis
Mark Pugh – AFRL Information Directorate – Image Processing
Andrew Noga – AFRL Signal Processor and EEG reference point
Aurel Lazar – Columbia University – Neuromorphic Time Encoding Machine
Ron Chapman – Nunez Community College – History of The Additive Model
Bill Copeland – Helios – HMAX analysis
Angel Estrella – University of Yucatan – Local Stability –Griffiss Institute
Alfredo Vega – AFRL Engineer – Linear Recursive Sequences
Todd Moon – Utah State University - Mathematics of Signal Processing (Book)
Andy Williams - AFRL- Program Manager, SERTA and SCORE
Yuriy Luzanov – AFRL Engineer – Introduced Bart Kosko’s BAM
E. James Cupples – AFRL – Speech under Stress
Joel Fleischman – U.S. Marine Veteran and private contractor
RhythmLink, Electrodes, Columbia, SC
G. Oliver, Behavioral Neuroscientist, conversations 2022
P. M. Carabin – Former USAF Guidance and Control Tech

Reconstructing feedback representations in the ventral visual pathway with a generative adversarial autoencoder, Al-Tahan, Yalda Mohsenzadeh, PLOS, 2021

Interictal high-frequency oscillations (80–500 Hz) are an indicator of seizure onset areas independent of spikes in the human epileptic brain, Jacobs et. Al., Montreal Neurological Institute, Epilepsia. 2008

Characterization of high frequency oscillations and EEG frequency spectra using the (damped-Oscillator) oscillator detector (DOOD), David Hsu et. al, Univ. of Wisconsin.

A Practical Guide to Wavelet Analysis, Torrence and Compo, Univ. of Colorado

Obeid, I., & Picone, J. (2018). The Temple University Hospital EEG Data Corpus. In Augmentation of Brain Function: Facts, Fiction and Controversy. Volume I: Brain-Machine Interfaces, Lausanne, Switzerland: Frontiers Media S.A.

Thank you SfN

James P. LaRue

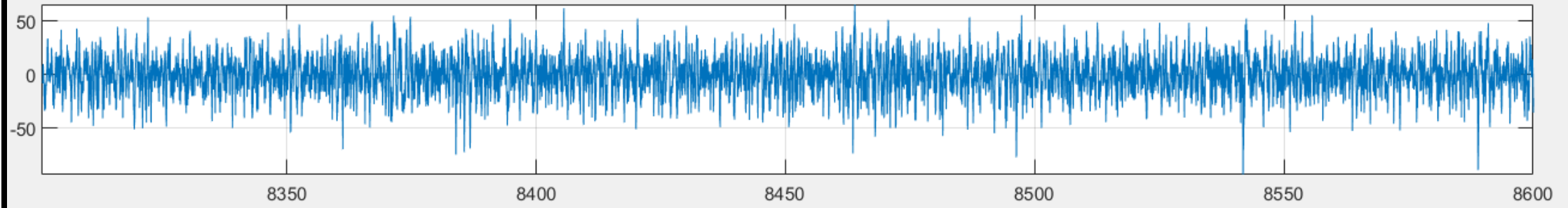
James@JadcoSignals.com

Joining Analog and Digital Communication Signals

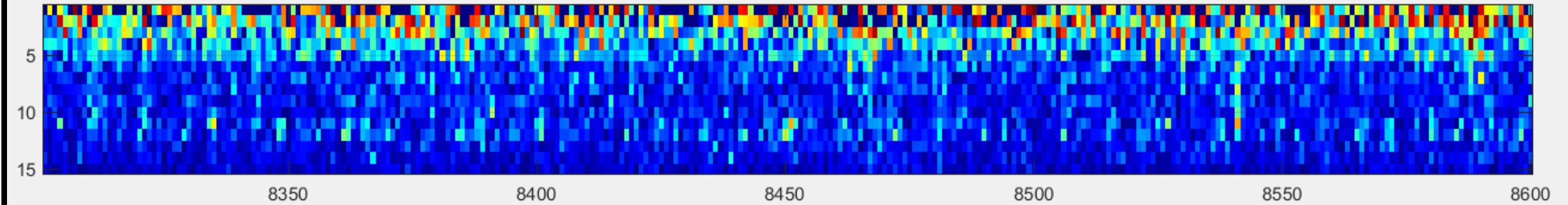
Back-up

No Seizure Recorded

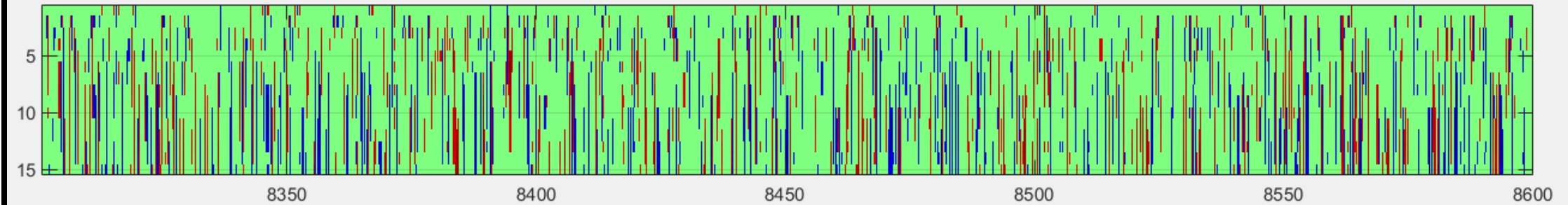
Time



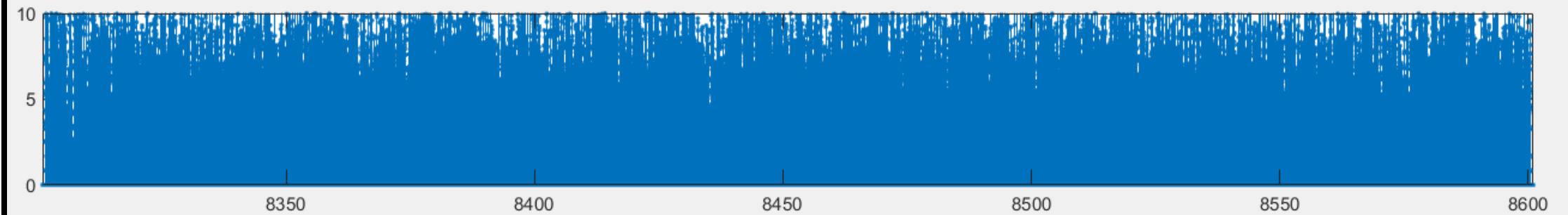
Window
Spectrogram



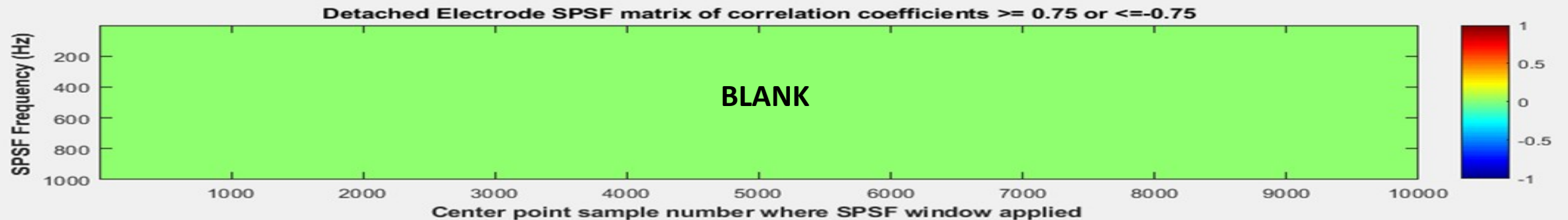
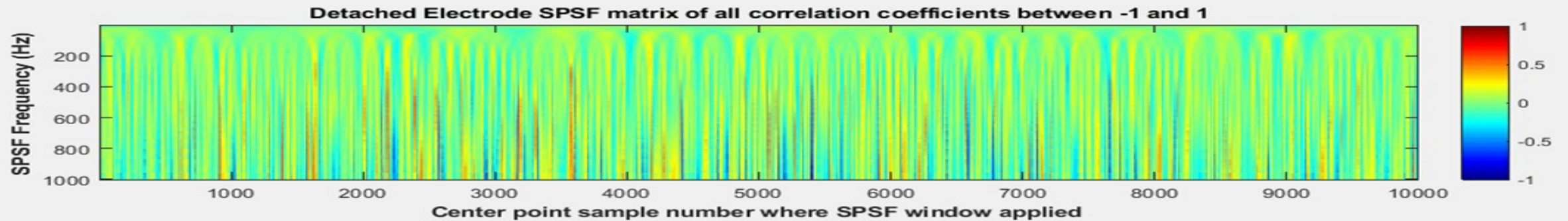
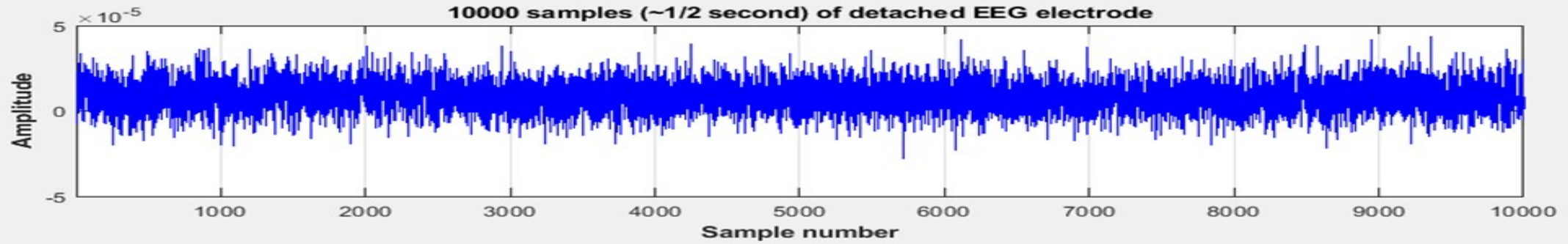
SPSF



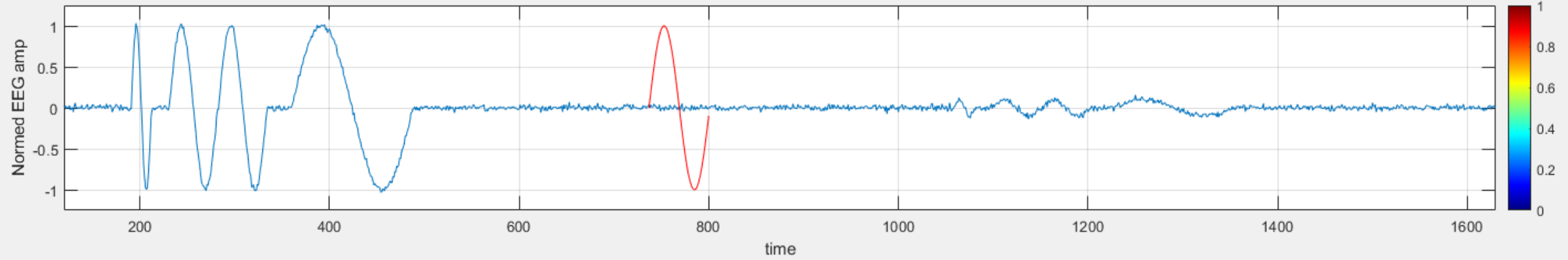
SPSF
Summed



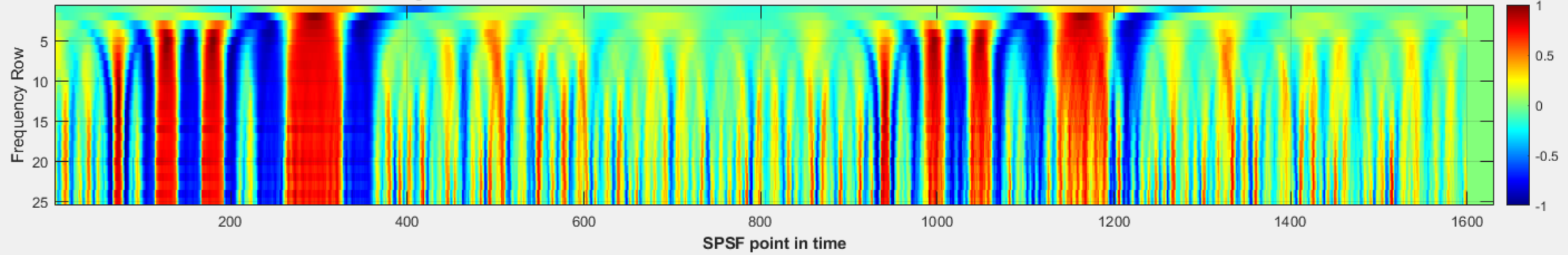
With electrode sitting on G-Tec's table, measures are taken, but no correlations above 0.75



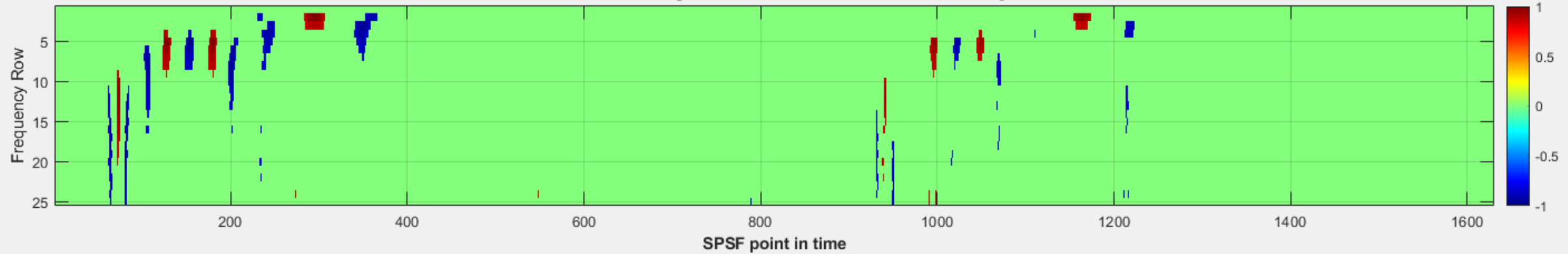
EEG SPSF search at 4 Hz



Sliding correlation coefficients with SPSFs isolates the occurrence of a beat



Thresholding isolates the exact frequency



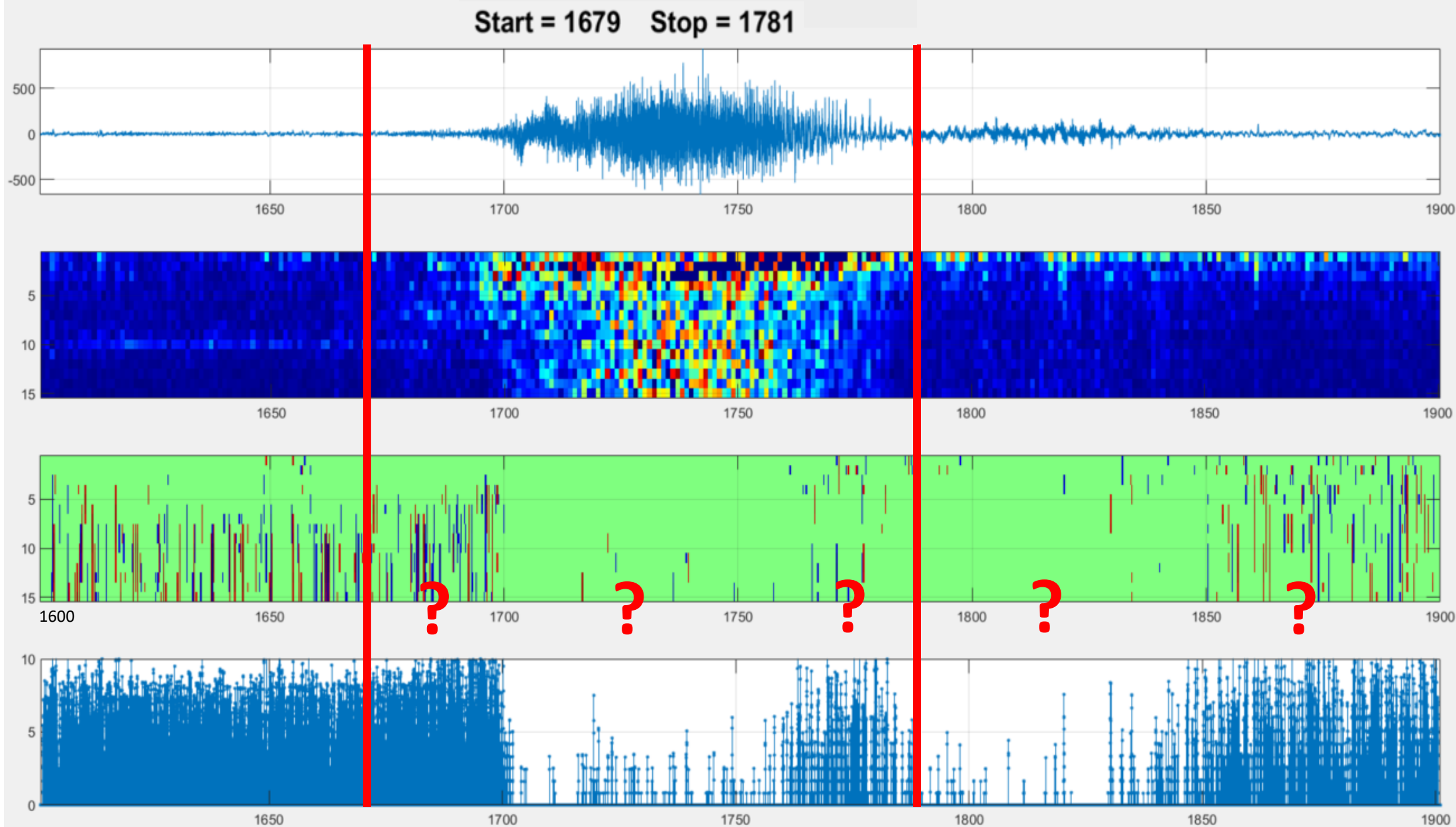
Example 1 EEG from MIT data-base (somewhat clean from 60 Hz)

chb04_28
F3-C3
256 Hz

Window FFT
one sec
no-overlap

SPSF
Corrcoefs
(4500)

SPSF
Summed



Thoughts on moving forward

Use RAINNE SPSF basis to measure brain activity in context of:

- Desensitization caused by societal pressure; life is devalued
- Can we get data leading up to (a suicidal) event?
- Simply needing better fidelity and resolution (detail, visualization)

Get the attention of VA/NAII and NIMH
(Veteran Affairs, National Artificial Intelligence Institute)
(National Institute of Mental Health)

Get more data here:

https://sccn.ucsd.edu/~arno/fam2data/publicly_available_EEG_data.html

But ideally,

Let's continue on with:

fast sampling rates,
a power supply that isolates 60 Hz,
and analysis that does not use:

- the Expectation Operator or
- the Fourier Transform with limits of integration set to $\pm \infty$

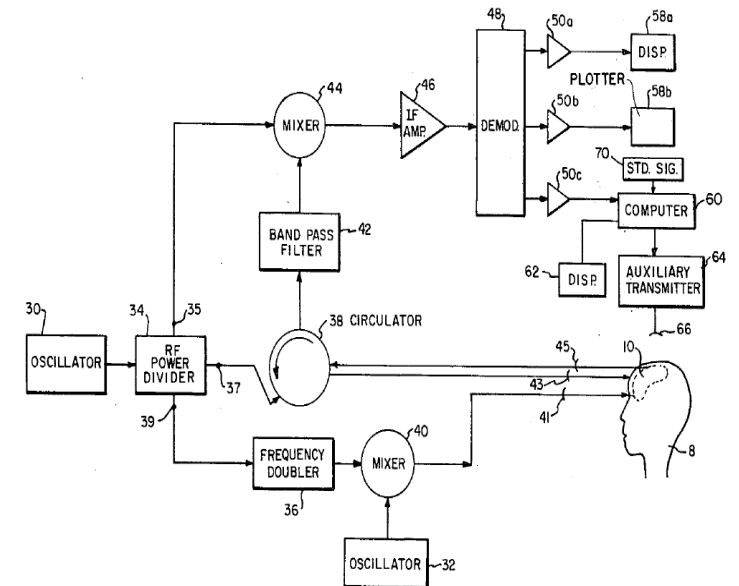
**Came across this (semi-drug-free)
medical solution using EM waves:**

APPARATUS AND METHOD FOR REMOTELY MONITORING AND ALTERING BRAIN WAVES

Inventor: **Robert G. Malech**, Plainview, N.Y.

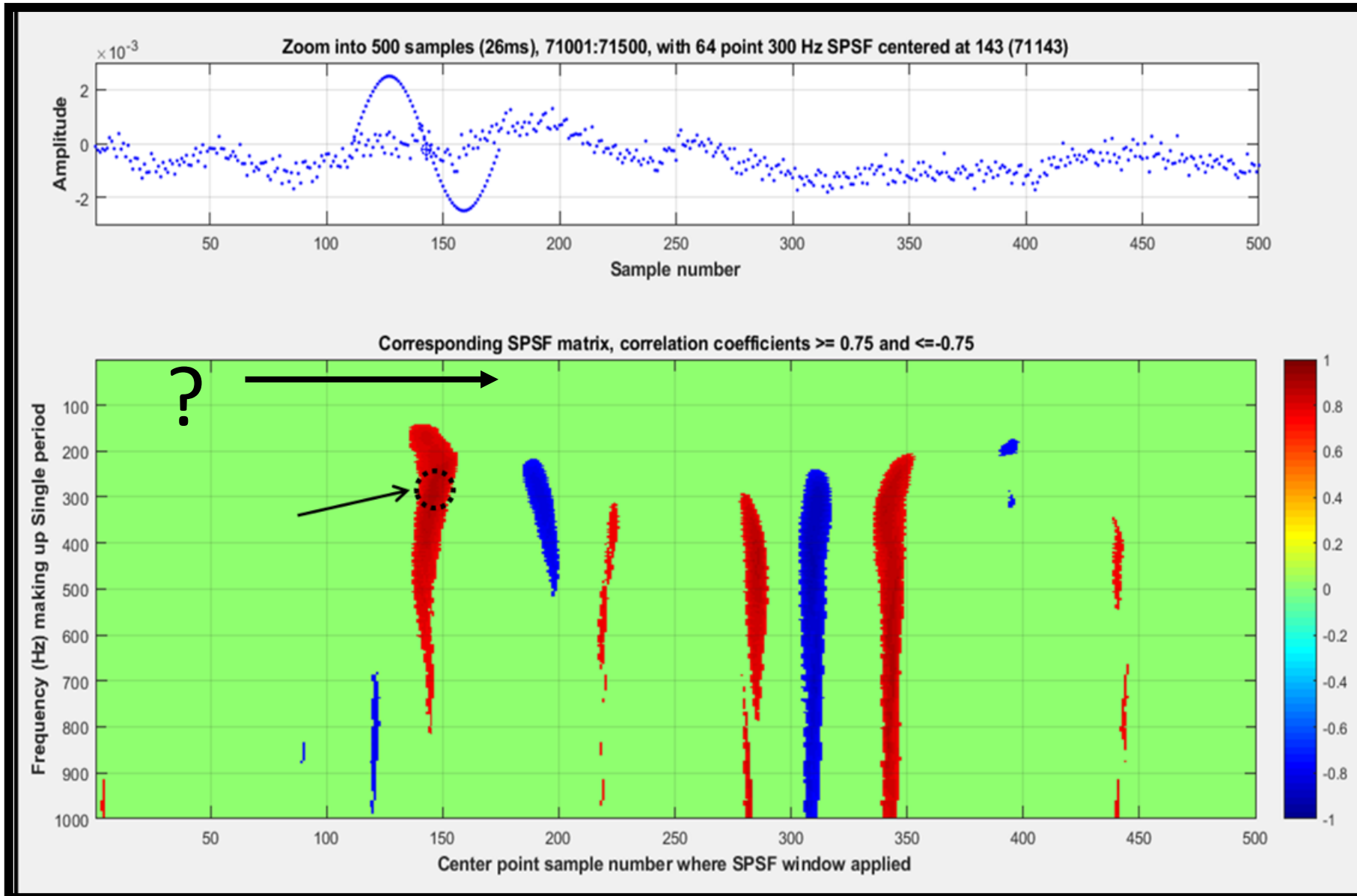
Assignee: **Dorne & Margolin Inc.**, Bohemia,
N.Y.

Filed: **Aug. 5, 1974** 3,951,134

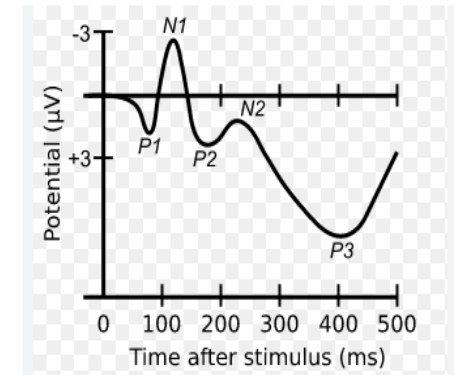


Saving the best for last:

The “clear” advantage with G-Tec 19 Khz sampling Rate (and no 60 Hz!)
But it took 2 minutes to calculate the 500,000 CC's covering 26 msecs, on my little ASUS



Event-related Potential (negative)



Wikipedia

EXAMPLE Scenario using MNIST

“Left eye” and “Right eye”
trained with 24 different Gabors
(*depth perception*)
(EO/IR)

1. Both systems trained to recognize an object
2. Left eye can't see incoming
3. Right eye is fine but the transmitter path is broken
4. So we use the Right Eye to pass information down to V3 and then utilize the AMM inter-connection to V3 of the Left Eye
5. Left Eye finishes prediction, (yes, successfully)

