Characterizing the non-chemical water treatment – advanced biological and electrochemical approaches

biosensor

Phyto sensor

bio-hybrid

Ψ ultra-weak

EIS

no chemistry

i infoceuticals

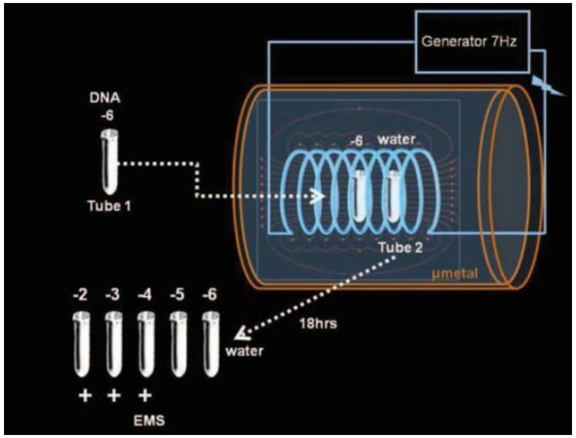
Dr. Serge Kernbach

CYBRES® beyond technology

18.10.18, the conference of physics, chemistry and biology of water

Non-chemical treatment

- reduction of chemical substances in water (to avoid harming the environment)
- multiple regulative directives in EC, USA, China, Japan, Russia
- hard limitations on using chemistry in water preparation

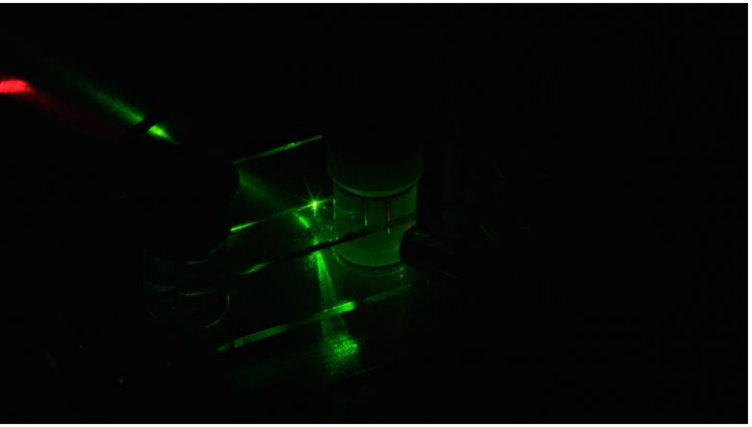


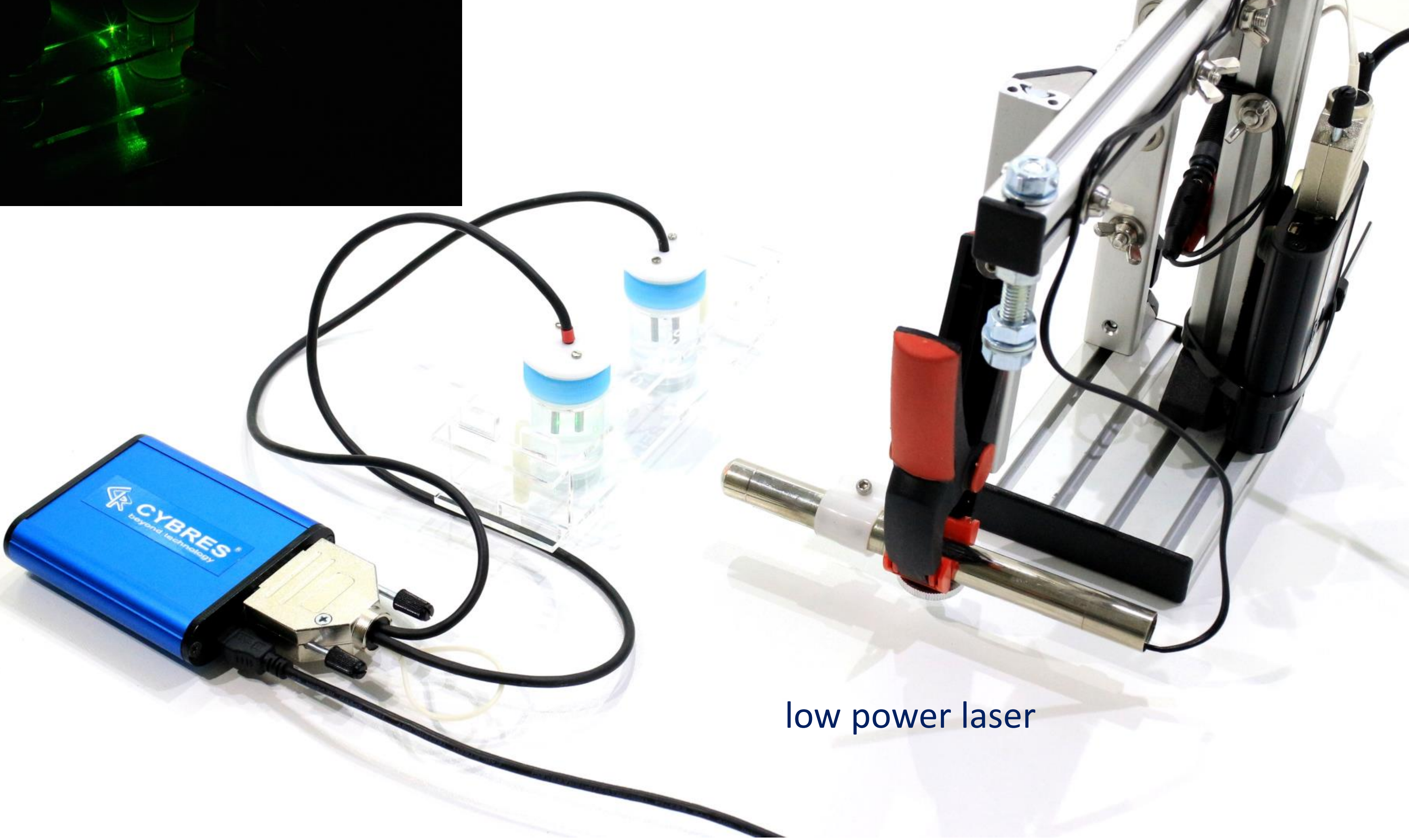
- water filters and preparation (e.g. cooling towers)
- new medical research and therapeutic approaches (*)
- multiple infoceutical products (e.g. IC medicals)
- "Qi/Ch'i/Qi gong" research and therapy
- ultra-low concentrations of substances

- include hydrodynamic cavitation, light/laser processing, treatment with modulated electing and magnetic fields, magnetic vector potential, and others
- extremely weak, difficult to measure (especially in infoceutical purposes)

(*) L. Montagnier, J. Aissa, E. Del Giudice, C. Lavallee, A.Tedeschi, and G. Vitiello, DNA waves and water, arXiv:1012.5166v1

Example: Low energy laser handling (Prof. Inushin, technology known from 80x-90x)





Does it work? Can we prove it?

“Can our customers/patients easily verify it?”

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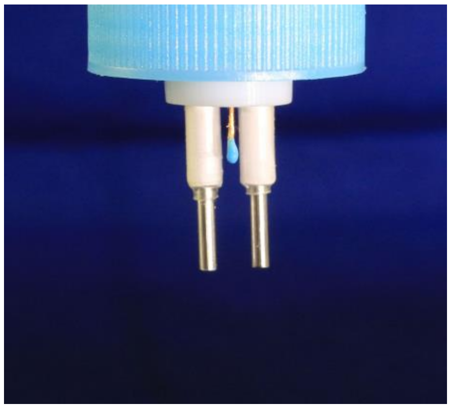
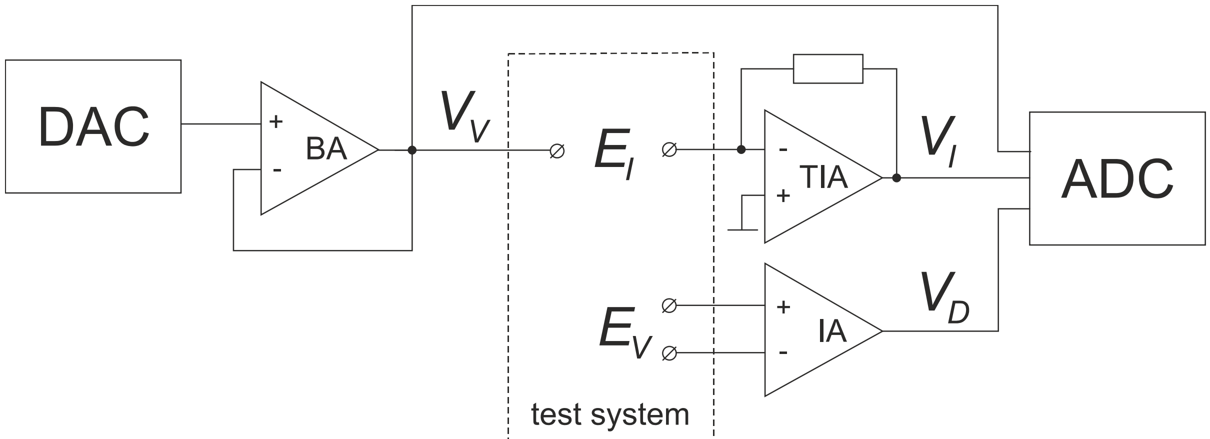
If something can't be measured does it mean it doesn't exist?

Electrochemical measurements. What is it?

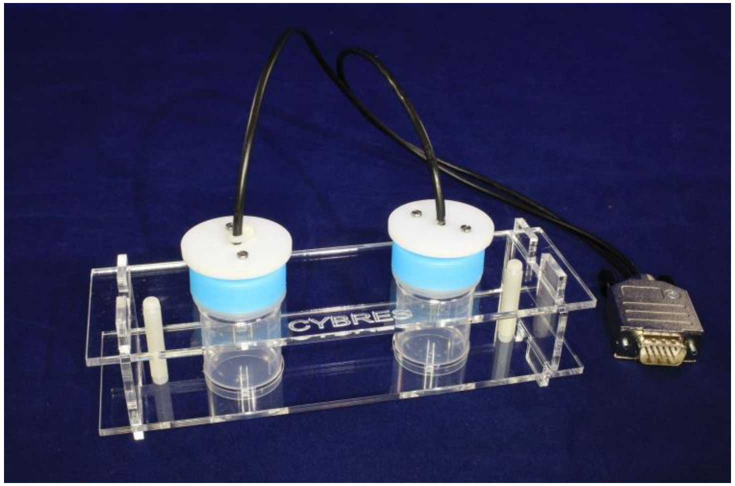
molecular and quantum scale effects appear on macroscopic scale as a change of ionic dynamics





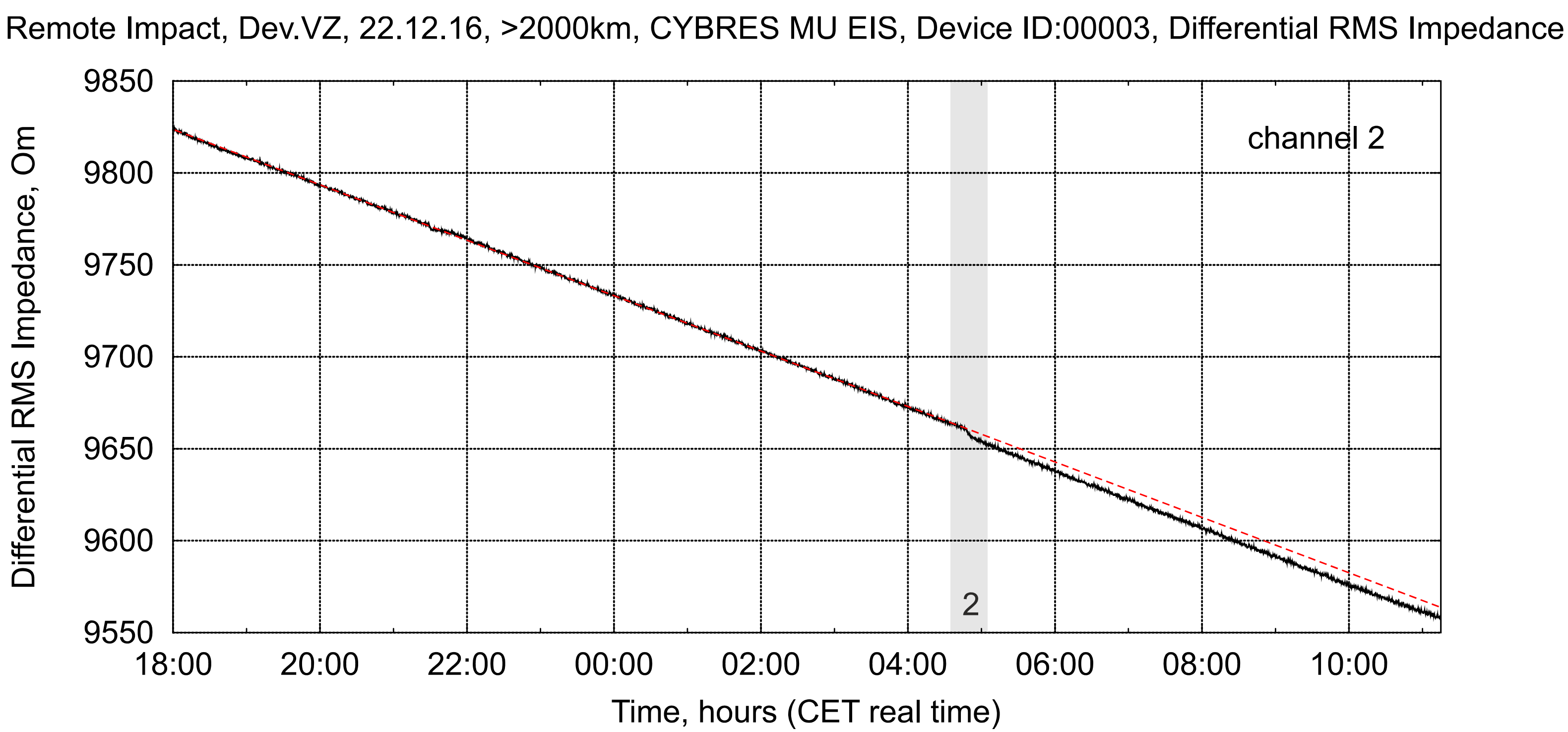
- Impedance (conductivity) at excitation frequency f
- Correlation and Phase between excitation and response signals
- Nyquist plot (Re/Im parts of signals)

- differential measurements (RMS and FRA)
- time-frequency patterns (vs. only frequency)
- 33 data channels with additional sensors



e.g. S.Kernbach, I.Kuksin, O.Kernbach, On Accurate Differential Measurements with Electrochemical Impedance Spectroscopy, WATER, 8, 136-155, 2017

Ionic dynamics during long-term EIS measurements



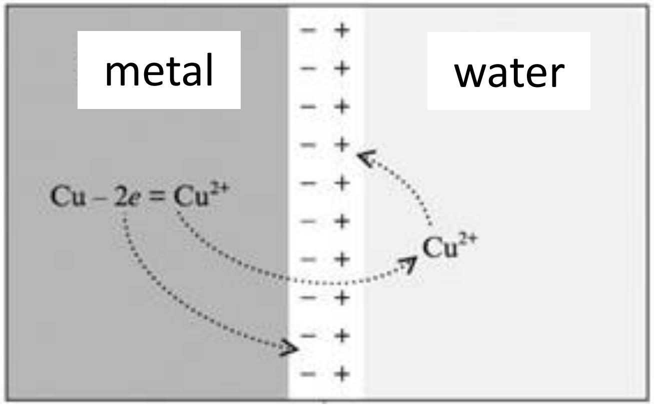
$$EC_t = EC_{25}[1 + a(t - 25)]$$

- no temperature/light changes
- no gas dissolving effects
- no mechanical impact
- no change of EM/E/H emission

- polarization effect, double electric layer
- ions diffusion in electric field
- self-ionization in electric field
- proton tunneling effect

S.Kernbach, V.Zamsha, Y.Kravchenko, Experimental Approach Towards Long-Range Interactions from 1.6 to 13798 km Distances in Bio-Hybrid Systems, NeuroQuantology, 14(3), pp.456 -476, 2016

Ionic dynamics during long-term EIS measurements



I.Persson, Hydrated metal ions in aqueous solution. Pure Appl. Chem., Vol. 82, No. 10, pp. 1901–1917, 2010

X6CrNiMoTi17-12-2 (1.4571, V4A, =SAE 316 stainless steel)

	C	Si	Mn	P	S	Cr	Ni	Mo	Ti
min.	-	-	-	-	-	16,5	10,5	2,0	5xC
max.	0,08	1,0	2,0	0,045	0,03	18,5	13,5	2,5	0,7

Table 1 Overview of M–O bond distance, calculated ionic radius, the ionic radius reported by Shannon [63], and the configuration of hydrated metal ions in aqueous solution.

Aqua complex	M–O distance	M^{n+}'s ion radius/Å	Shannon	Configuration	Refs.
$Mn(H_2O)_6^{2+}$	2.20	0.86	0.830 (HS)	Octahedron, pale pink	10,11
$Fe(H_2O)_6^{2+}$	2.12	0.78	0.780 (HS)	Octahedron, pale green	10,11
$Ni(H_2O)_6^{2+}$	2.055	0.715	0.690	Octahedron, green	35
$Cr(H_2O)_6^{3+}$	1.96	0.62	0.615	Octahedron, blue–green	26

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Ionic Diffusion and Proton Transfer in Aqueous Solutions under an Electric Field: State-of-The-Art

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University of Paris-Saclay, France

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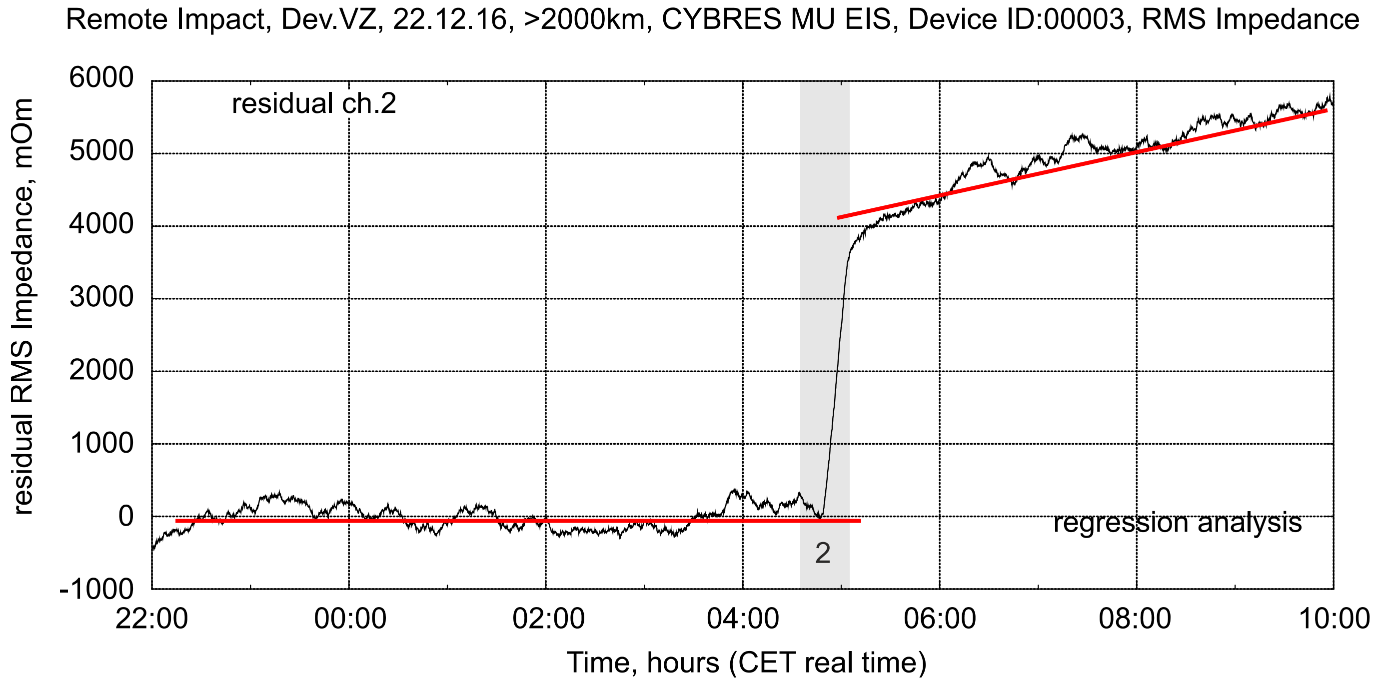
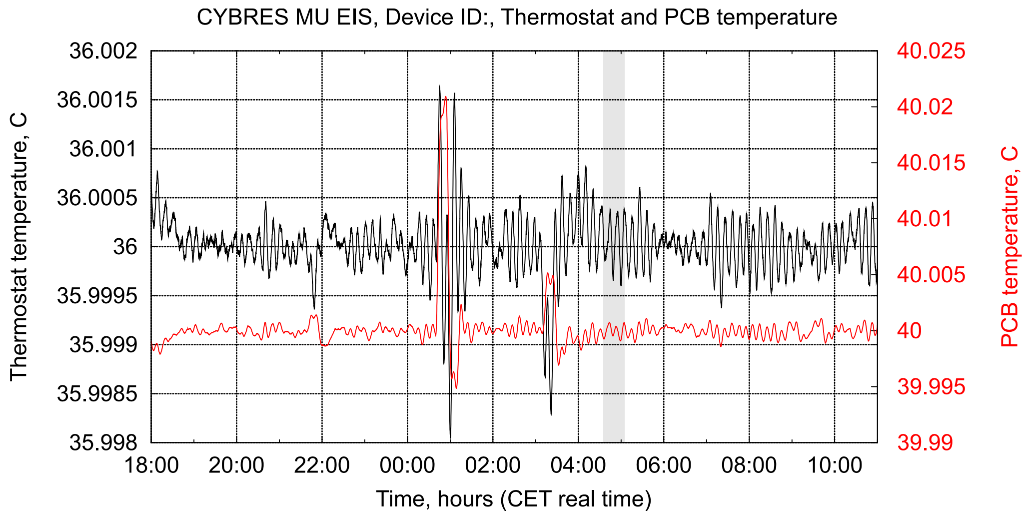
Most of the properties and anomalies describing the behavior of water are somehow related to the hydrogen bonded (H-bonded) network [1-3]. Albeit the features of H-bonds have been investigated and depicted by an impressive amount of research, the way in which some external conditions–such as the inclusion of ionic species–affect the three-dimensional H-bonds arrangement is wrapped up in a high degree of uncertainty.

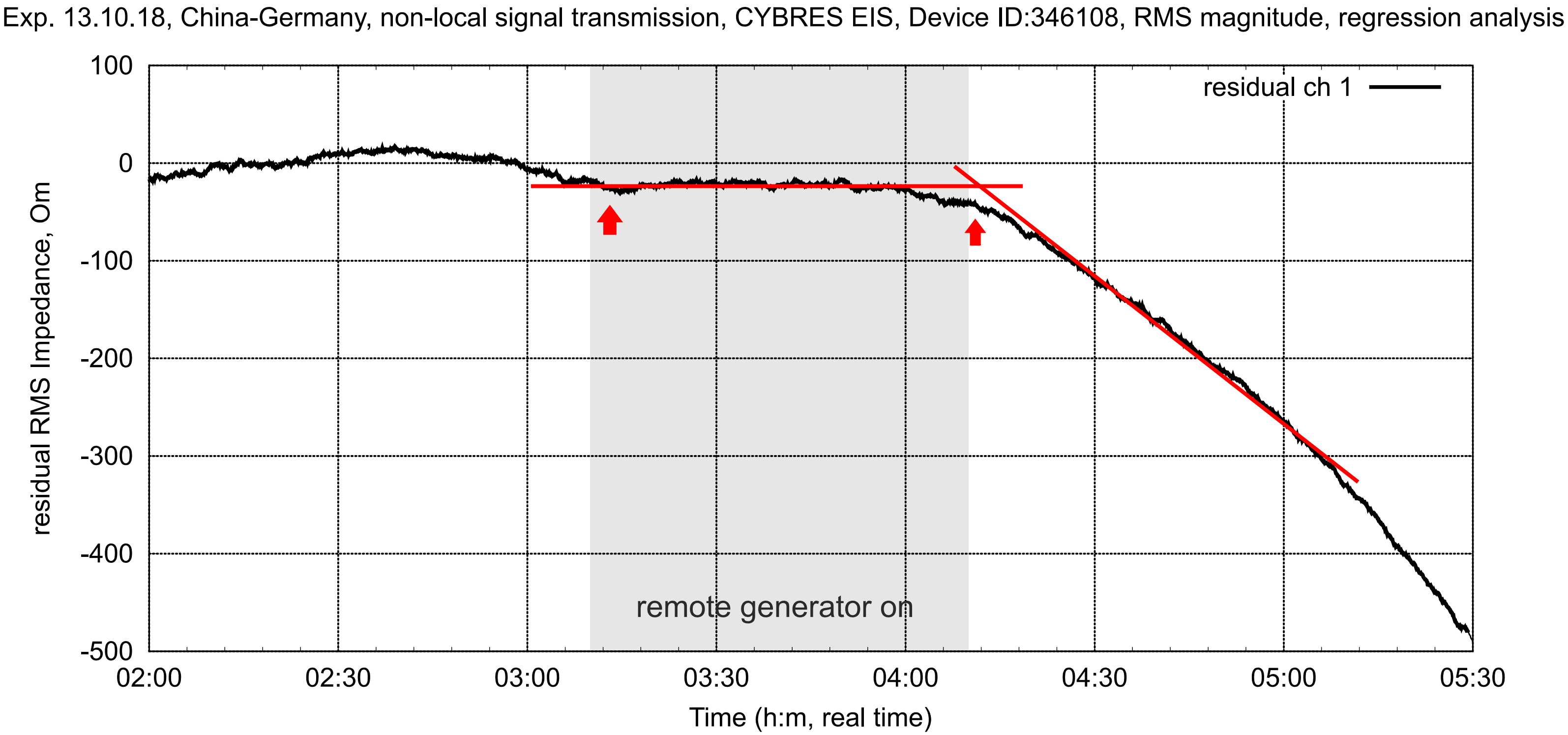
In all cases, a subtle balance between electrostatics, quantum mechanics (i.e., partial orbital sharing), and thermodynamics governs the delicate behaviour of the hydration process. The complexity of the problem is witnessed, inter alia, by the fact that there is no general consensus on the spatial extent of the effects induced by the inclusion of an ion in bulk water.

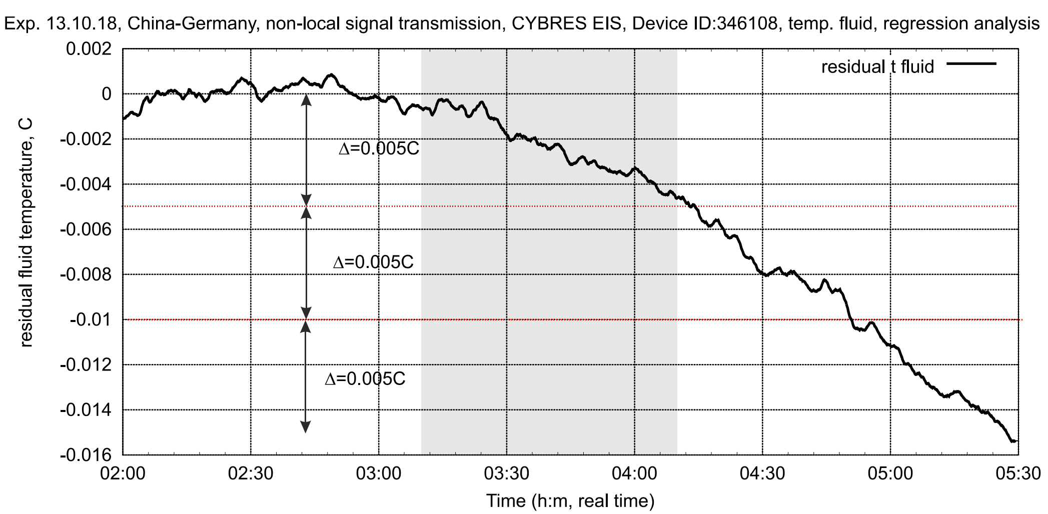
Moscow (Russia) – Stuttgart (Germany), 22.12.16, 2000km





Langfang (China) – Stuttgart (Germany), 13.10.18, 7900km





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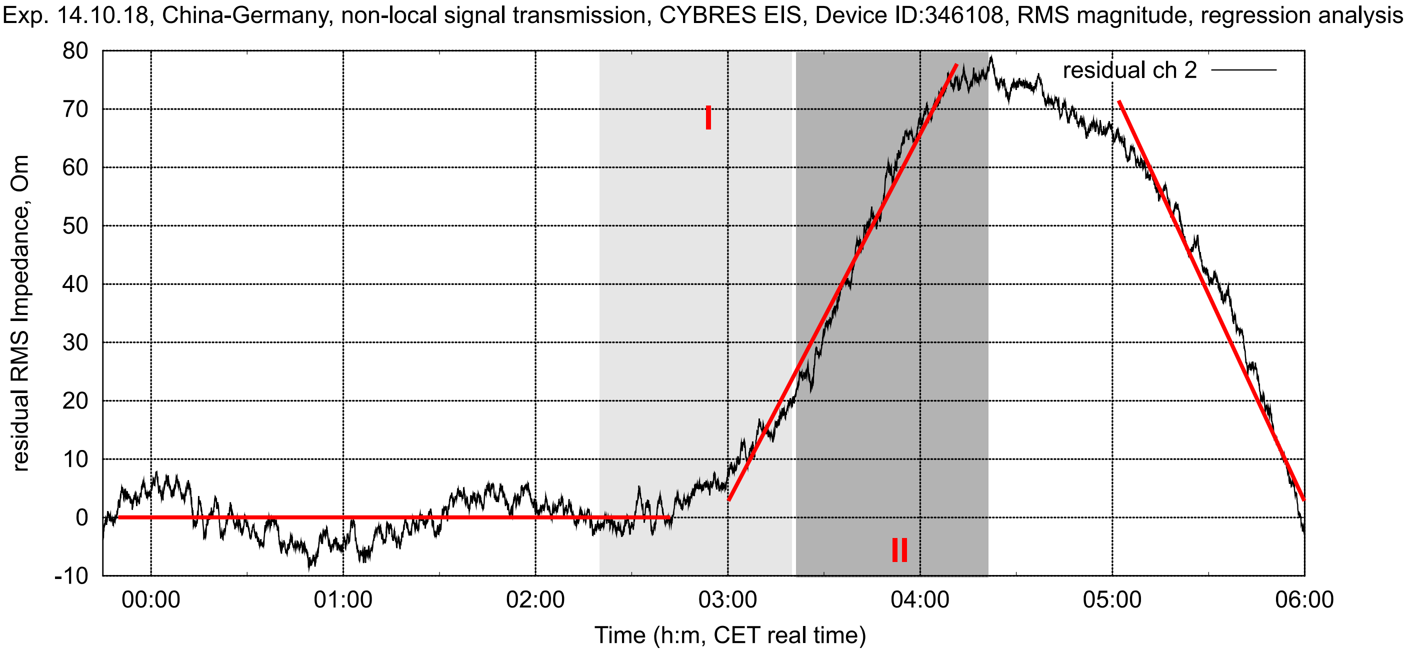
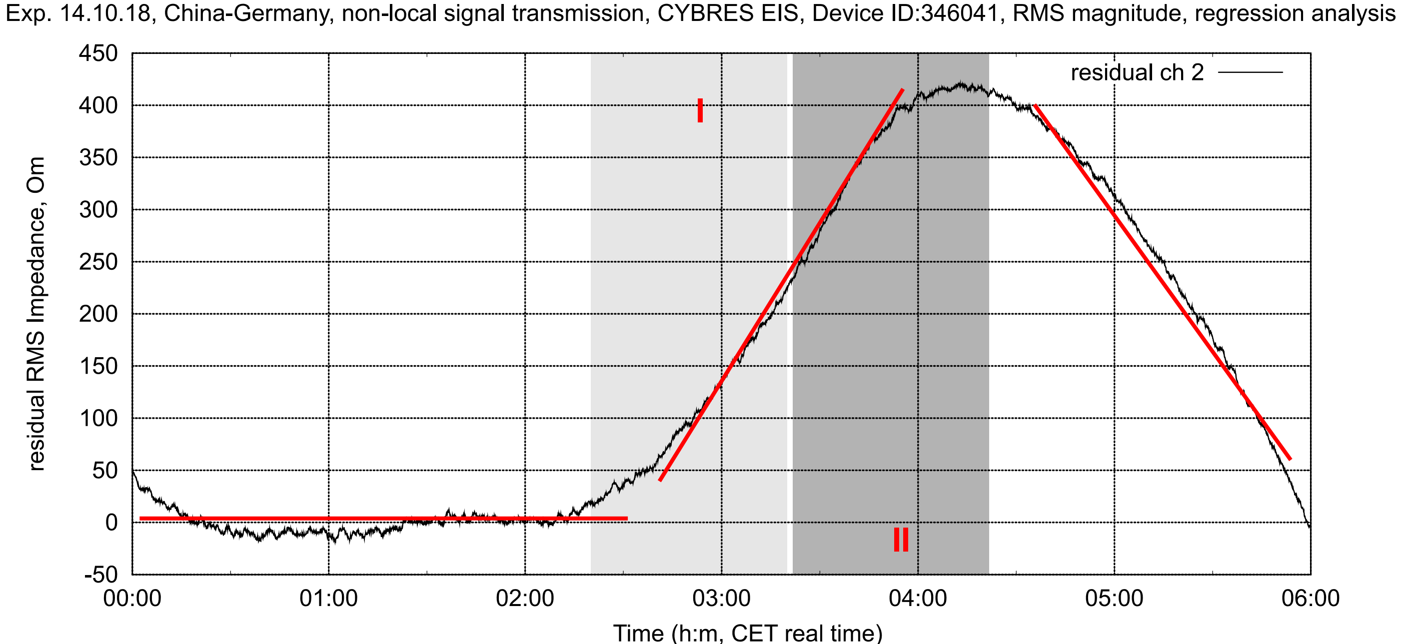
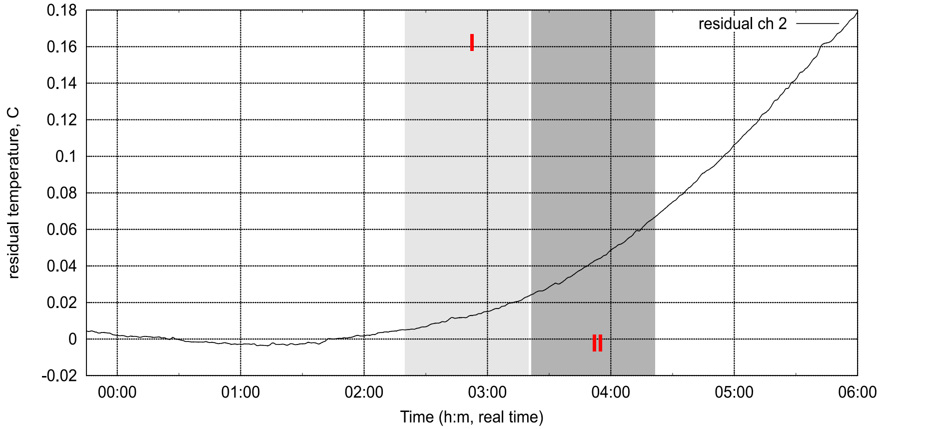
Langfang (China) – Stuttgart (Germany), 14.10.18, 7900km



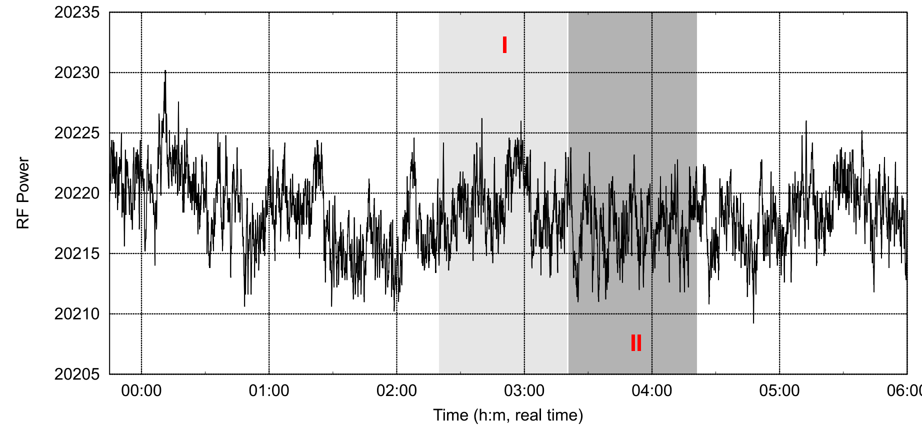


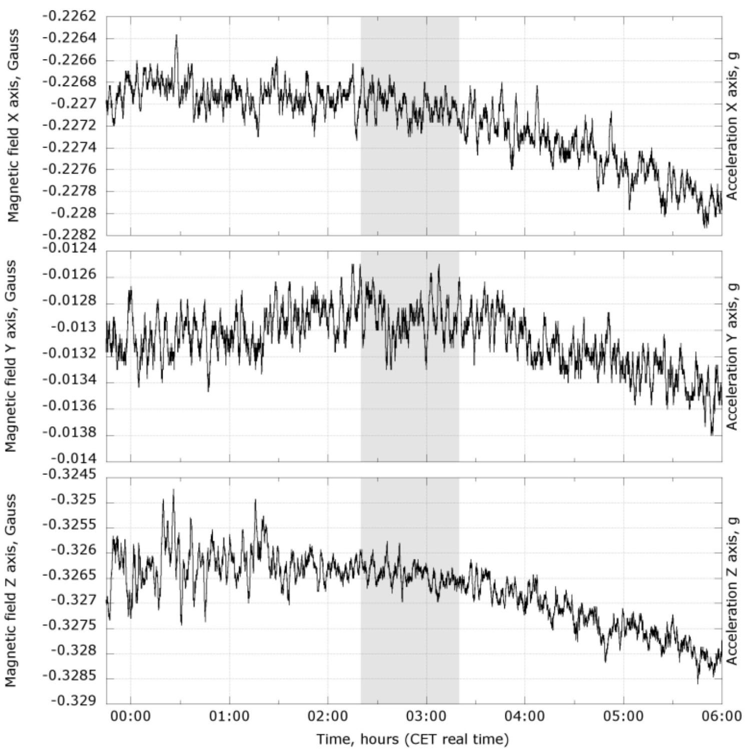
Langfang (China) – Stuttgart (Germany), 14.10.18, 7900km (local environmental data – no local impact)

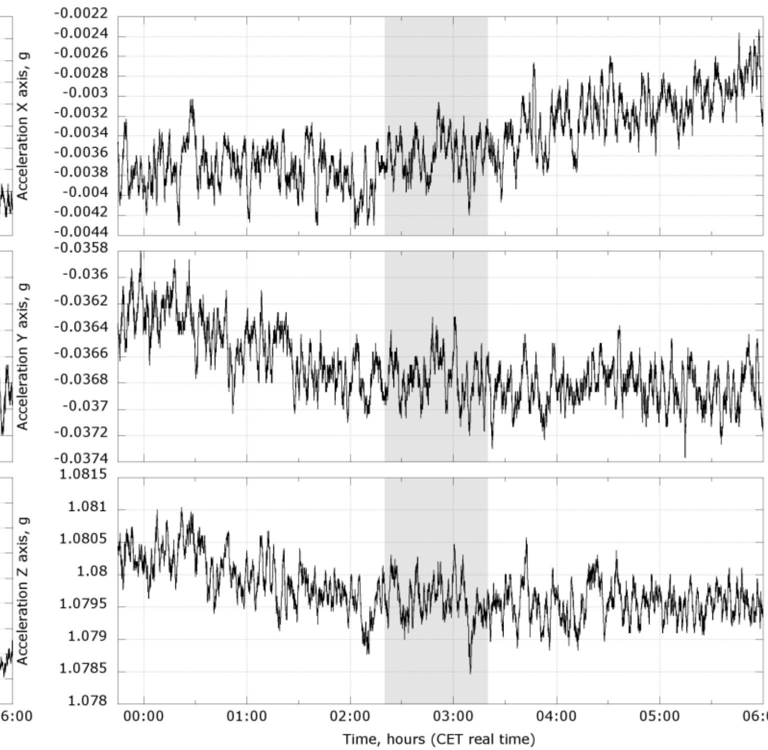
Exp. 14.10.18, China-Germany, non-local signal transmission, CYBRES EIS, Device ID:346108, temperature, regression analysis, ch.2



Exp. 14.10.18, China-Germany, non-local signal trans., CYBRES EIS, Device ID:346108, External RF power sensor 450MHz-2.5GHz







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Langfang (China) – Sofia (Bulgaria), 6700km (attempt of live-demonstration during the workshop)

Non-chemical treatment

Change of „coefficient“ (inclination) of ionic dynamics:

- Ionic diffusion (double electric layer, “electrode potential”)
- Hydrogen bonded network in water
- Self-ionization constant (ionic product)
- Rate of proton tunneling effect (?)

Ionic response

characterization of treatment

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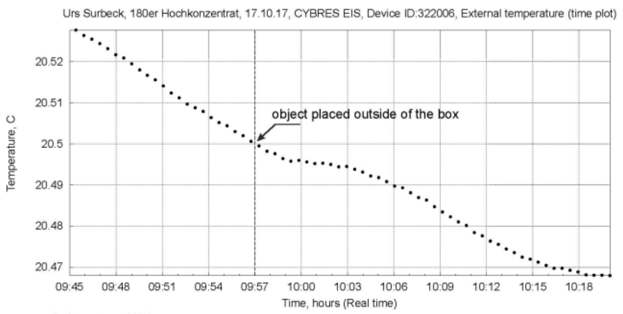
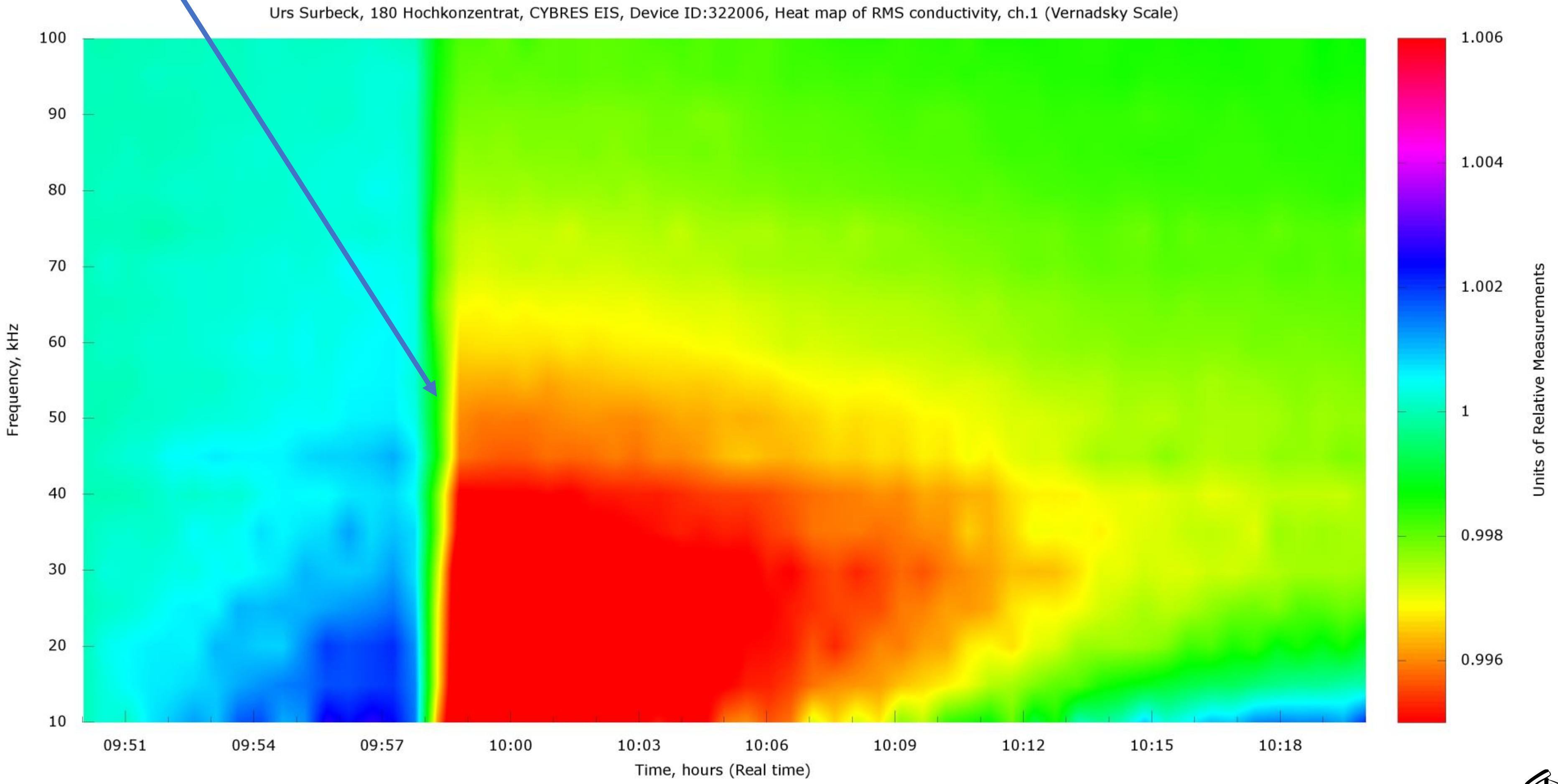
Non-chemical treatment with Urs Surbeck Hochkonzentrat

placed close to electrodes
outside of thermobox





S.Kernbach, On Symbols and Mems (rus), IJUS, 19-20(6), 120-148, 2018

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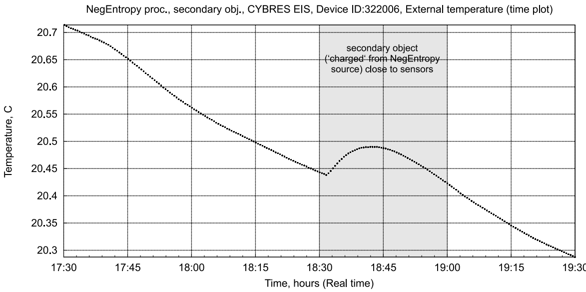
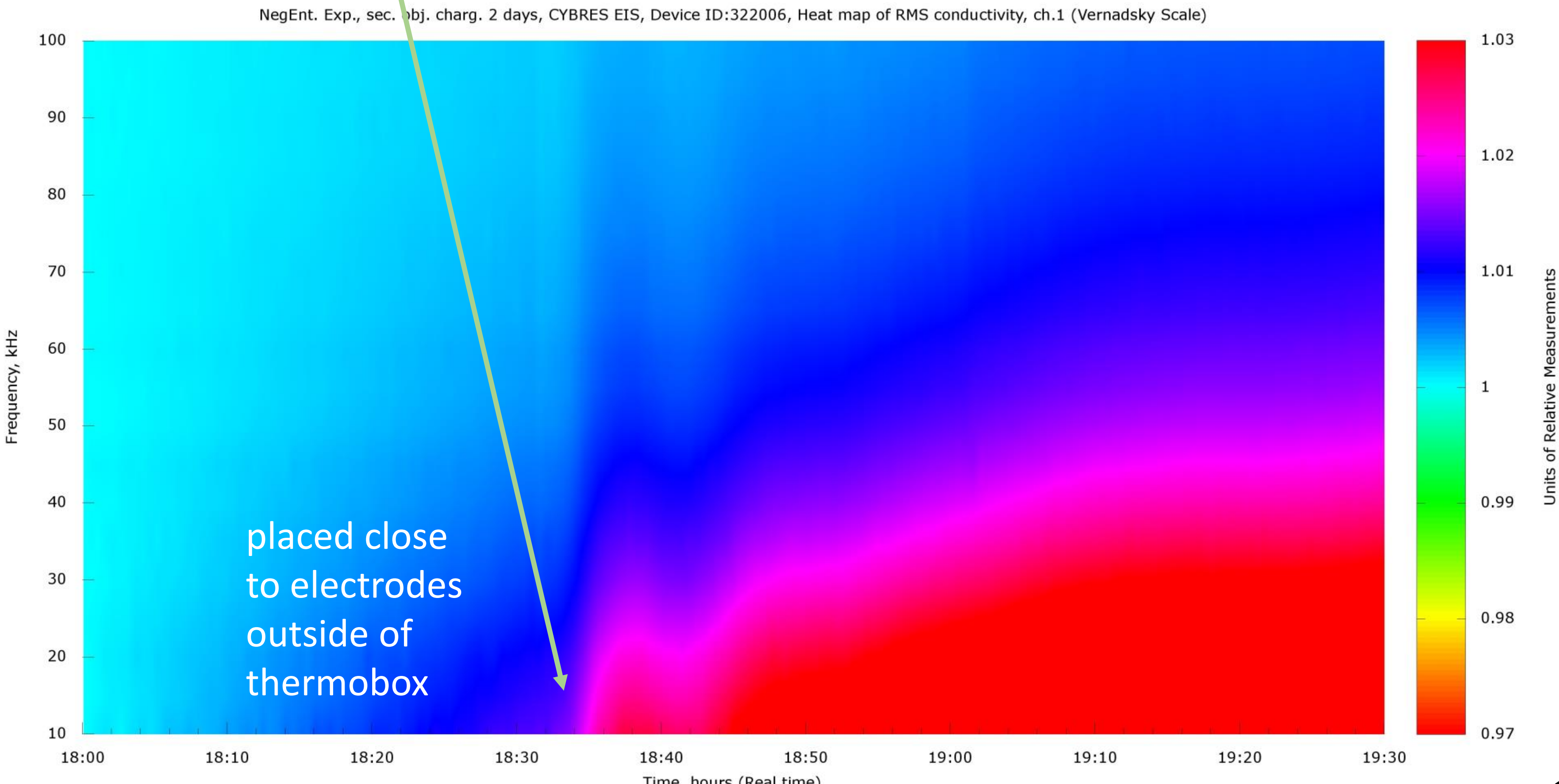
Non-chemical treatment with NegEntropic source

water





S.Kernbach, On Symbols and Mems (rus), IJUS, 19-20(6), 120-148, 2018

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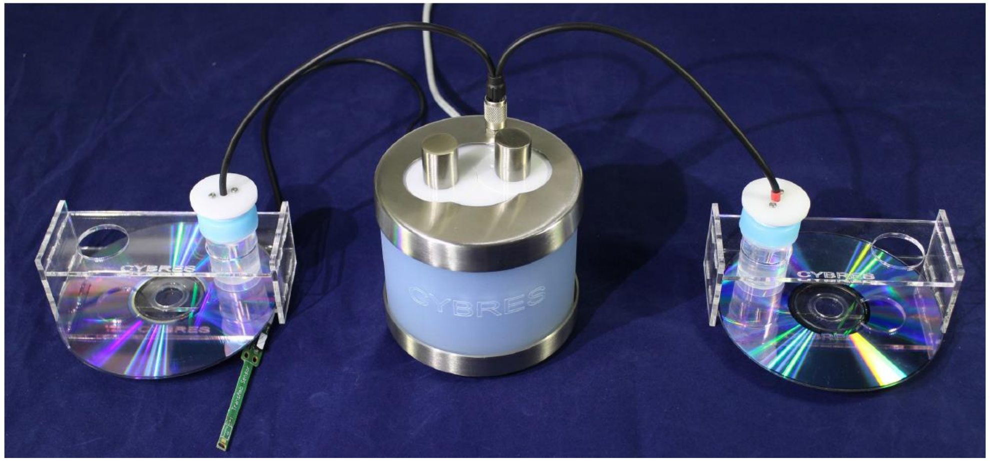
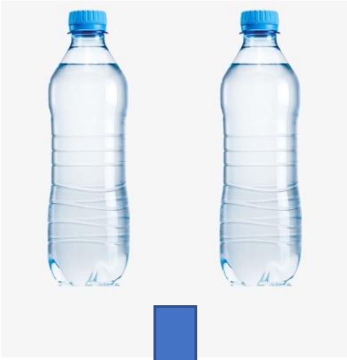
dynamics of ionic response is characteristic for non-chemical treatment

handling during measurements



analysis of pre-handled fluid



additional excitation necessary

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How to analyse the ionic response?

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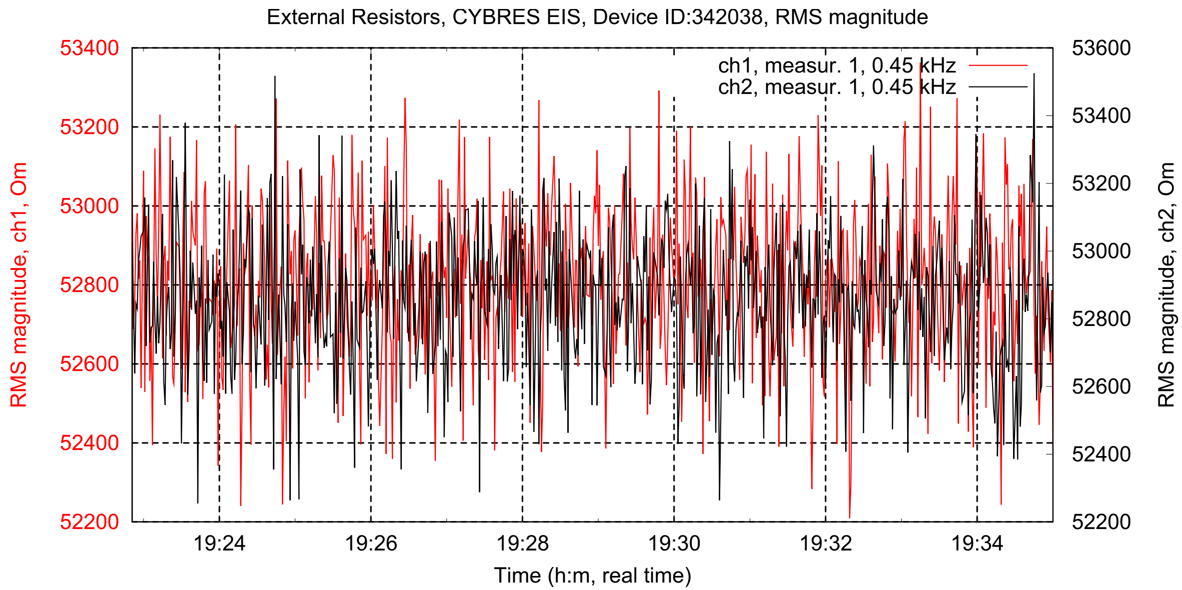
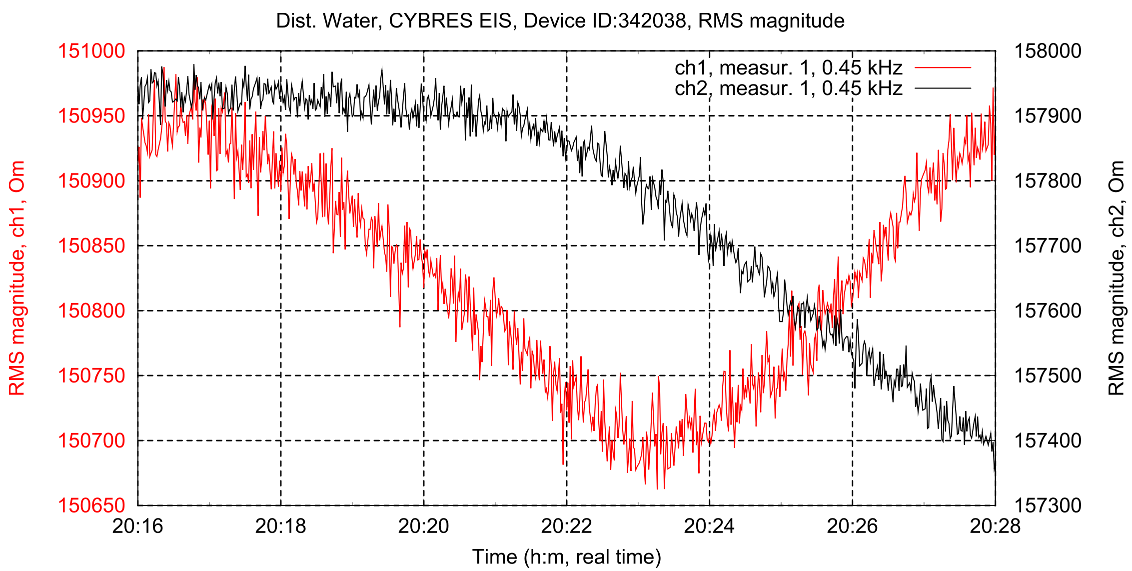
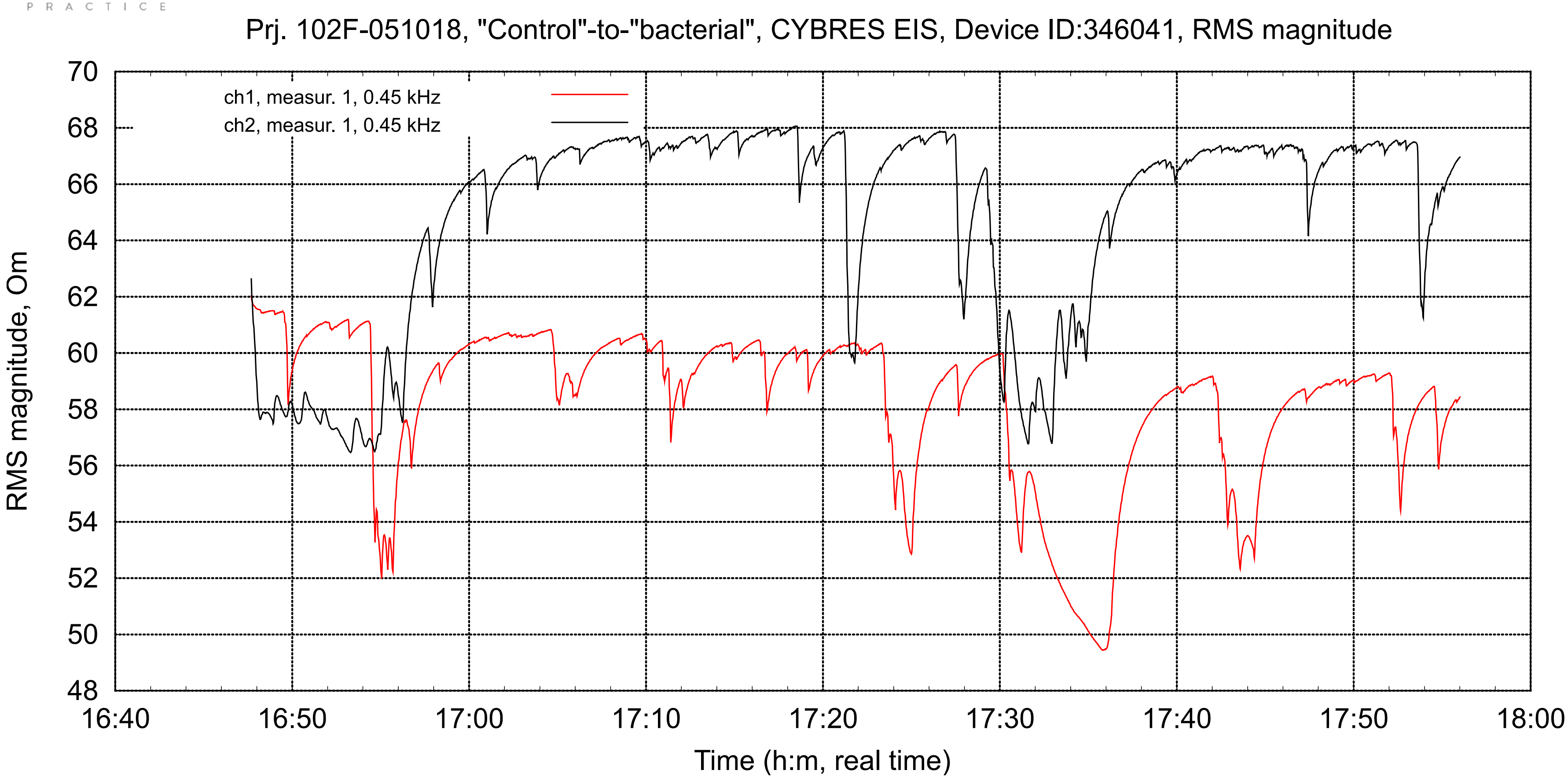
noise dynamics of low-conductive water/material





noise dynamics of high-conductive water/material



a physiological solution (saline solution): it involves a large number of additional effects

Analysis of electrochemical noise with statistical moments

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i. \tag{1}$$

The second statistical moment is the variance

$$Var(x_1, ...x_n) = \frac{1}{N-1}\sum_{j=1}^{N} (x_j - \mu)^2, \tag{2}$$

its square root represents the standard deviation

$$\sigma(x_1, ...x_n) = \sqrt{Var(x_1, ..., x_n)}. \tag{3}$$

The third moment is the skewness

$$Skew(x_1, ...x_n) = \frac{1}{N}\sum_{j=1}^{N} \left[\frac{(x_j - \mu)}{\sigma}\right]^3 + k_s, \tag{4}$$

and the fourth moment is the kurtosis

$$Kurt(x_1, ...x_n) = \frac{1}{N}\sum_{j=1}^{N} \left[\frac{(x_j - \mu)}{\sigma}\right]^4 + k_k. \tag{5}$$

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Analysis of electrochemical noise with statistical moments

Application Note 24. Analysis of electrochemical noise for detection of non-chemical treatment of fluids

Serge Kernbach

***Abstract*—This application note describes the statistical module of CYBRES EIS device. It explains the main methodological and technical aspects, settings and provides examples of measurements and obtained results. The statistical module is enabled in EIS, biosensor and phytosensor applications, it is implemented as post-processing of measured data by the DA module, performed in real time. The statistical description allows characterizing the non-chemical treatment in reliable and well reproducible way. Application of this approach in signal scope mode enables performing an express analysis with the measurement time of 4.4 ms. Calibration and different measurement strategies for non-chemical treatment**

impedance does not change in time) to non-stationary systems. It means that the excitation $V_V^{f,t}$ and response $V_I^{f,t}$ signals depend not only on the frequency f but also on time t [2]. Since the created by EIS electric field interacts with self-ionization process (this involves several quantum effects [3]), the continuous EIS is sensitive to micro- (e.g. quantum) and macro- factors applied to samples during the measurements and allows observing them on a macroscopic scale as a change of impedance in real time.

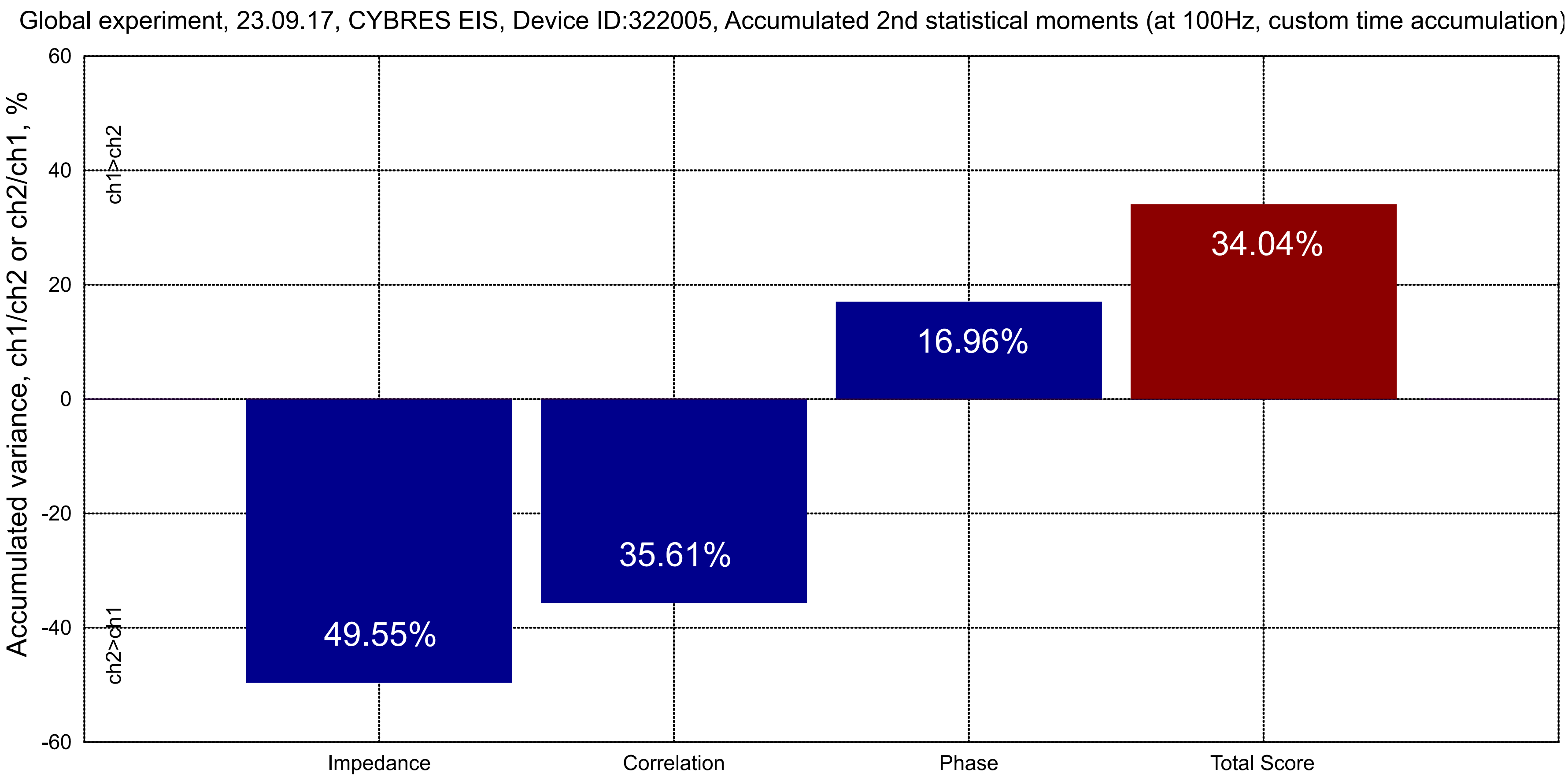
video

measurement mode: signal scope
statistical module enabled

- single measurement time: 4.4 ms
- N of processed values: 8400
- statistically significant measurements

Analysis of electrochemical noise with statistical moments, **Global experiment 2017**

DST Foundation



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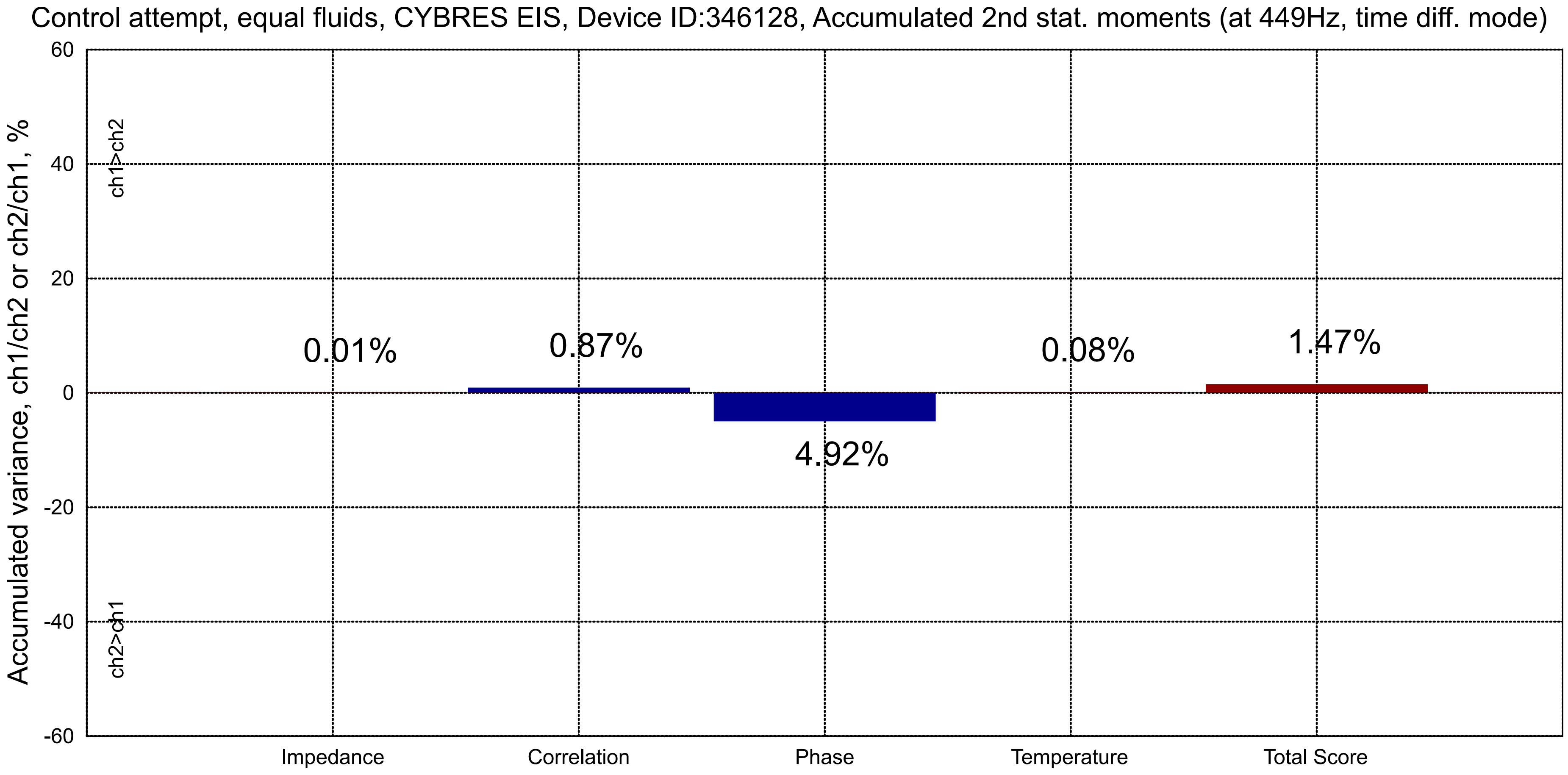
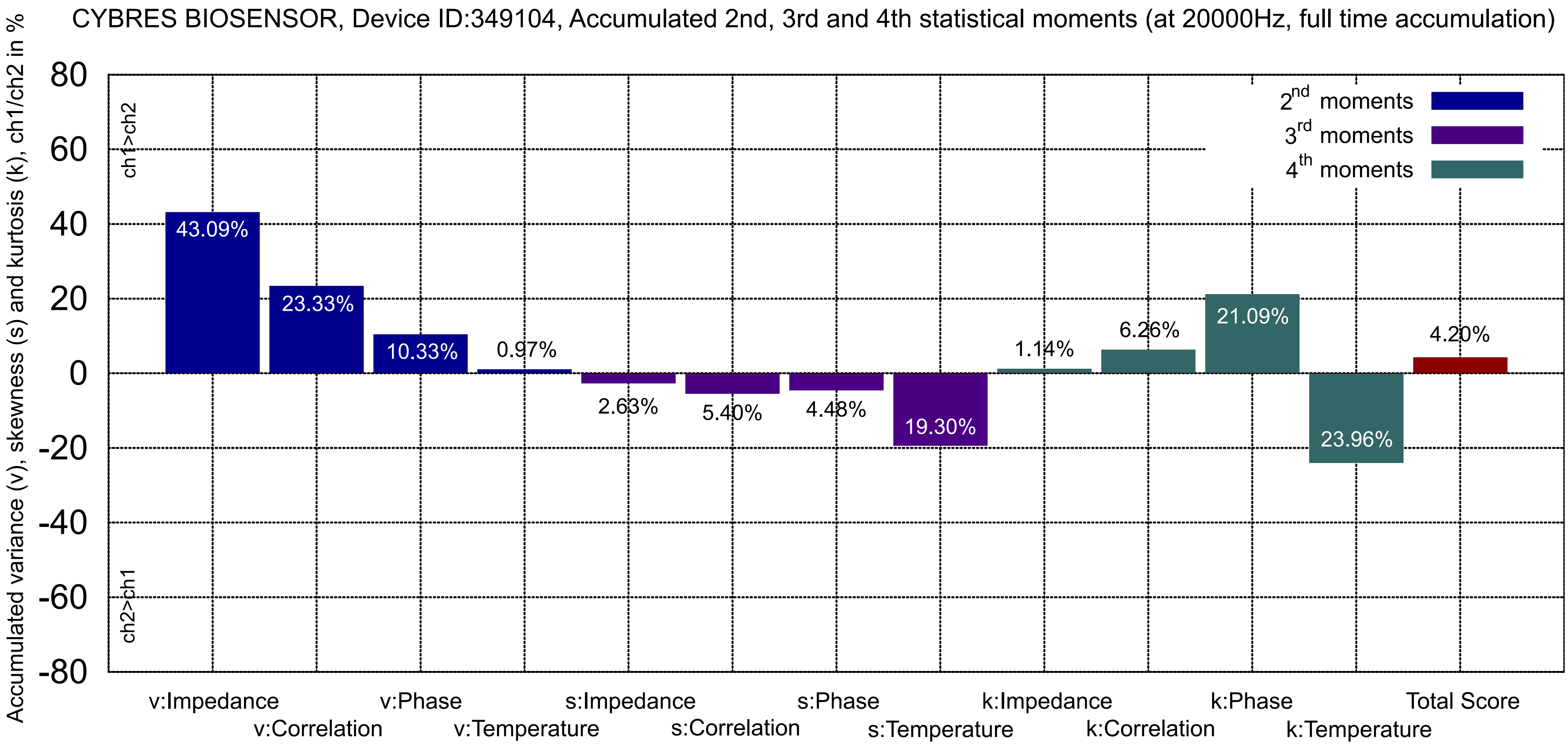
Analysis of electrochemical noise with statistical moments, Control Attempt, Equal Fluids



34% vs 1.5% -- clear result (!)

Characterization with 2nd-4th statistical moments



characterization based on 12-component vector

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video

multi-parametric characterization of non-chemical treatment

in real time with statistical DA processor

Analysis of pre-handled fluids requires additional optical/magnetic/thermal excitation

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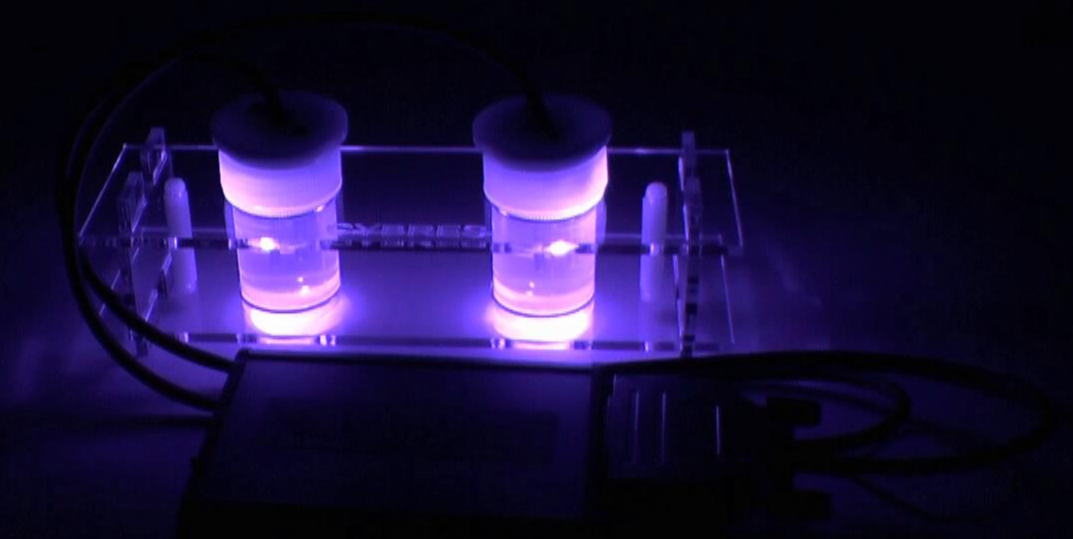
video

Excitation Spectroscopy

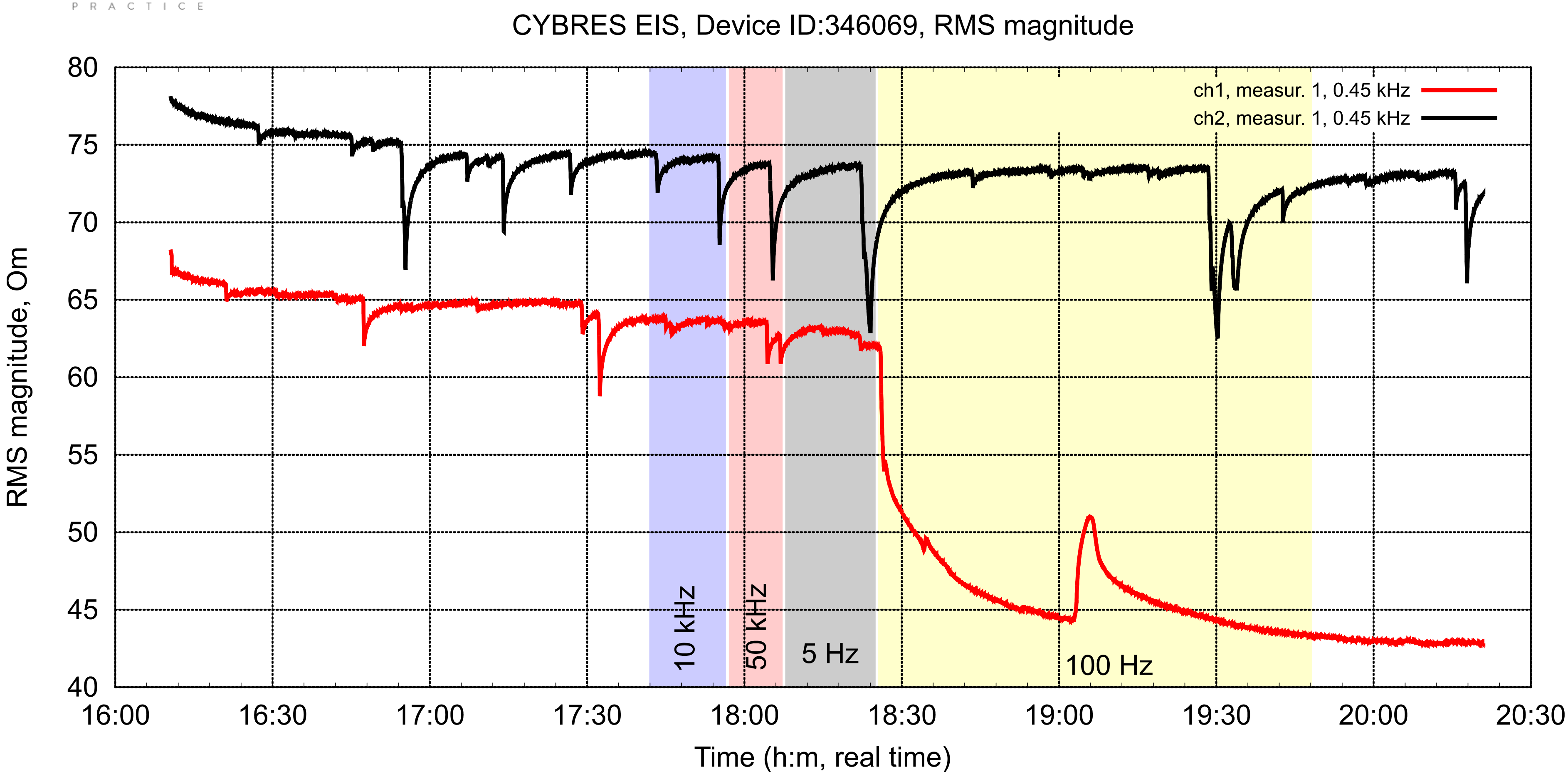


new MU3 features for bio-chemical EIS measurements

Example of EIS analysis with optical excitation

ROSCOP PRACTICE

Technology developed
by Frédéric Roscop



clear qualitative difference between channels

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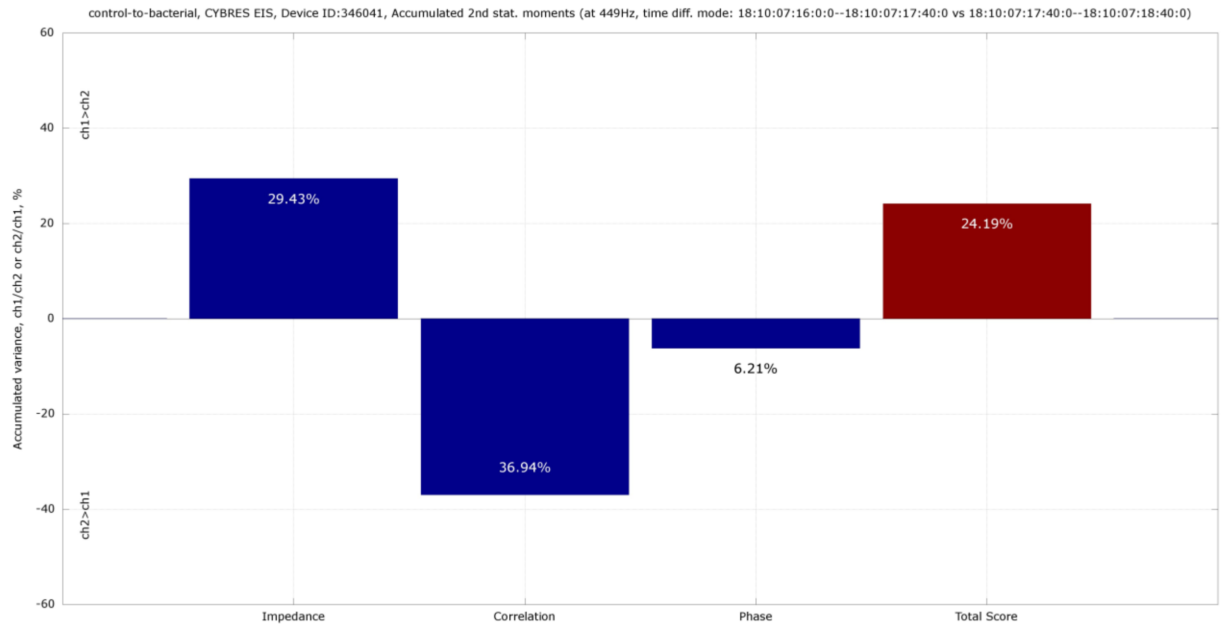
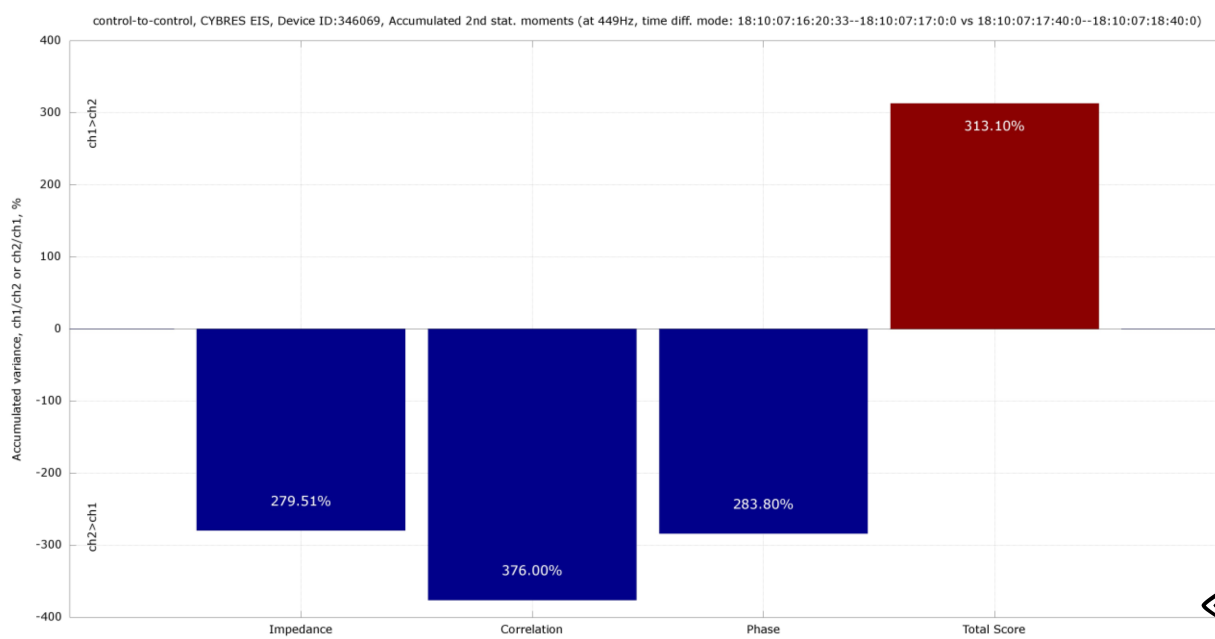
Example of EIS analysis with optical excitation

ROSCOP PRACTICE

Technology developed by Frédéric Roscop



clear numerical difference between channels



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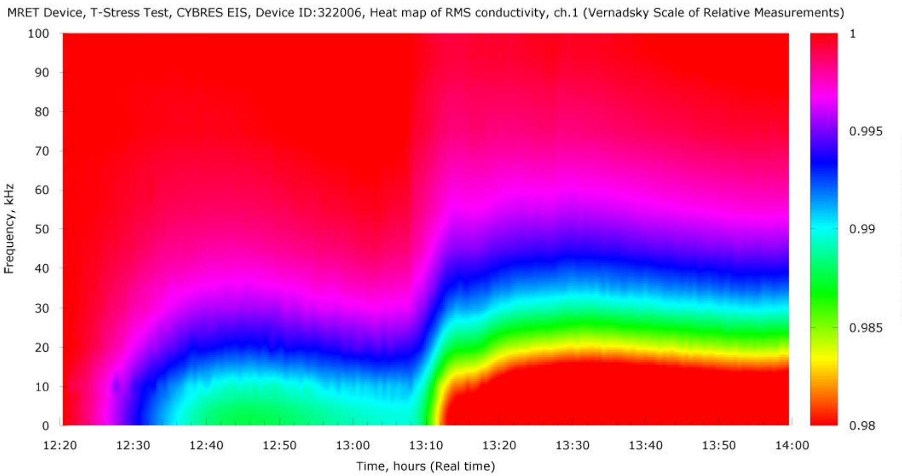
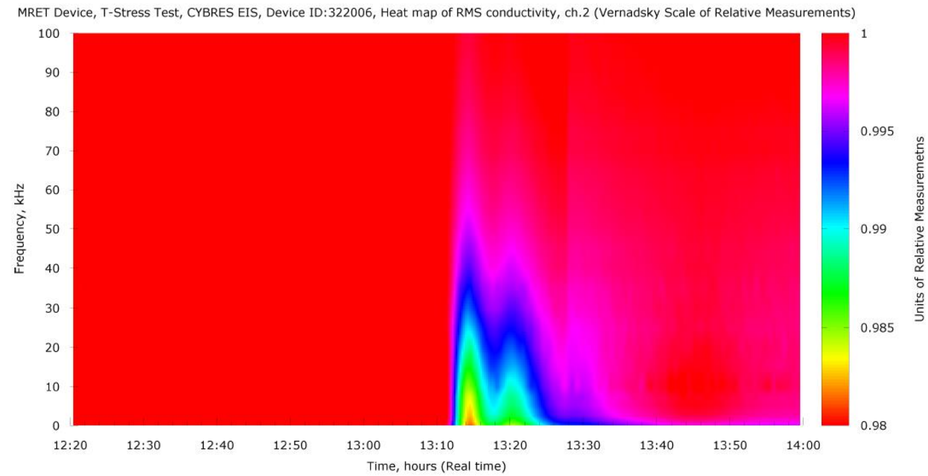
Example of EIS analysis with thermal excitation

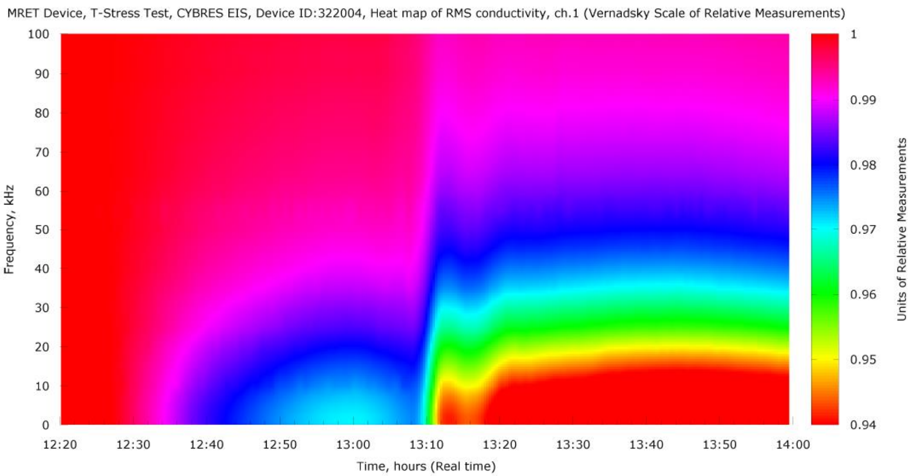
MRET technology by Dr. I.Smirnov



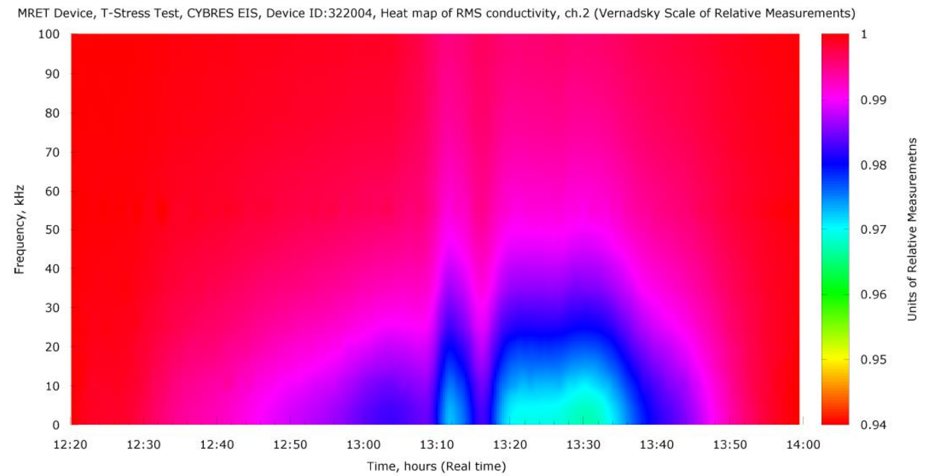
(c)



(d)



experiment



control

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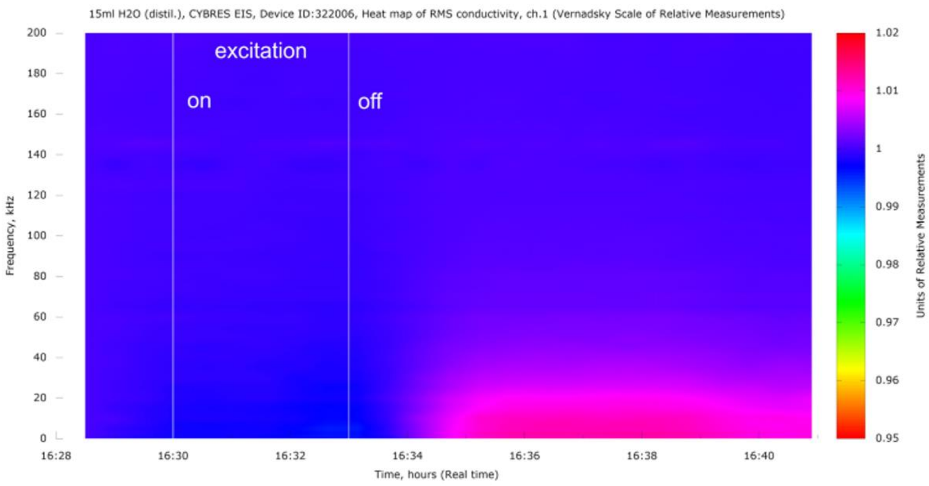
Example of EIS analysis with optical excitation (ultra-low concentrated solutions)



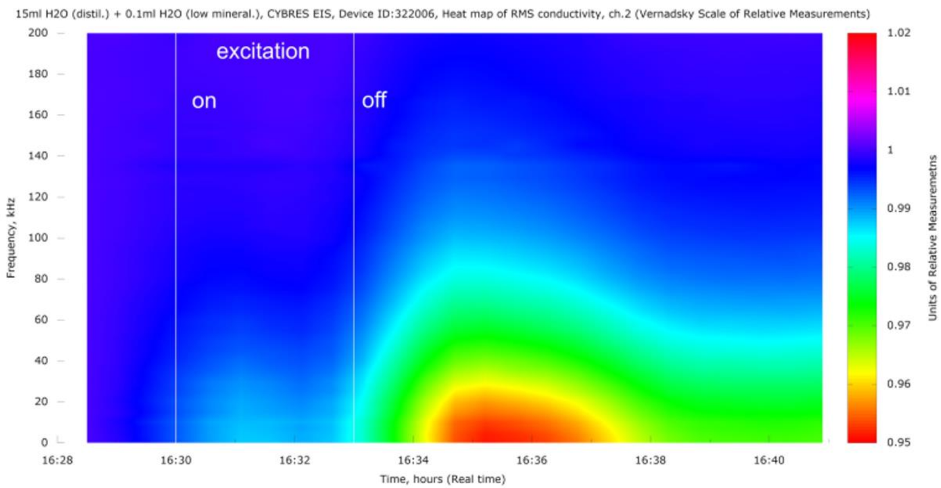


Figure 3. Example spectrograms of two water samples with optical excitation: **(left)** distilled H_2O; **(right)** 3 droplets of low-mineralized water (ion contamination10^{-3}-10^{-4}%) were added to the first sample. Different time-frequency patterns are well observable.

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Example of EIS analysis with optical excitation (complex biochemical fluids, wine & honey)

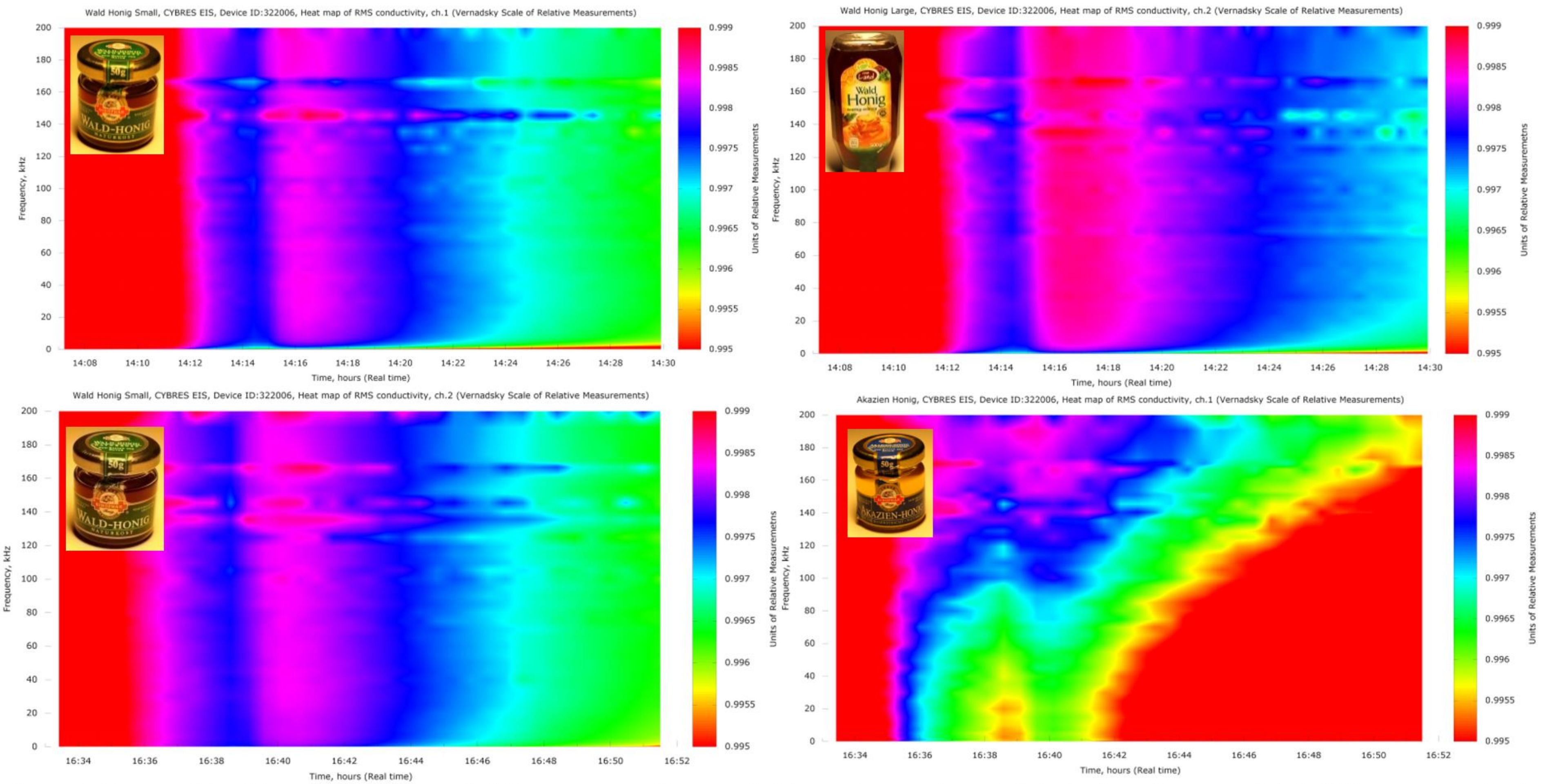

Figure 4. Tests to identify equal, similar and different sorts of honey, **(left)** equal sorts, **(top right)** similar, **(bottom right)** different sorts. Optical excitation is applied.

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video

time-frequency
excitation patterns

HORIZON 2020

E-SPECTR

Project ID: 800860
Funded under: H2020-EU.1.2.1. - FET Open

Excitation Spectroscopy Sensor

From 2018-09-01 **to** 2020-02-29, ongoing project

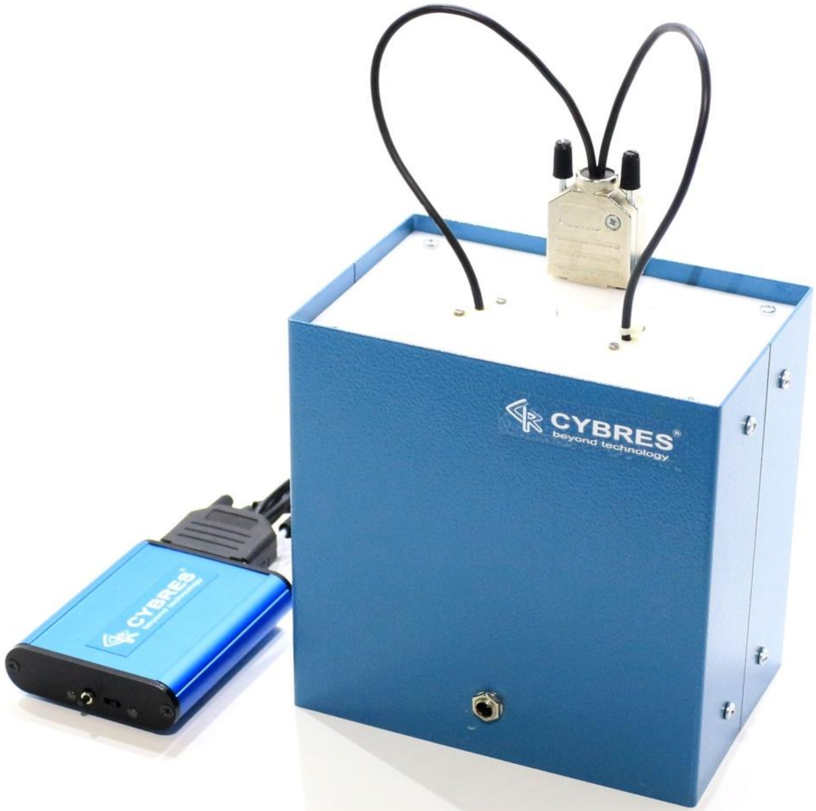
Objective

This sensing technology is based on the excitation-response dynamics of samples (organic objects and materials, tissues or fluids) embedded into alternating electric field. The system of samples-in-electric-field is excited in optical, magnetic or thermal way. Varying the frequency of the e-field, an analysis of excitation patterns over the frequency and time delivers information about structure, behavior and dielectric/electrochemical properties of objects and materials. Fully operational prototypes of the excitation spectrometer are produced; they demonstrated a high sensitivity and resolution of this approach, for instance, the sensor is able to detect small physicochemical differences between samples. The innovative applications are detections of low-concentrated chemical contaminations and non-chemical treatments in water quality monitoring, and an express identification of complex biochemical substances in field conditions (demonstrated in wine/honey production). The technological and economic impacts – as the enabling technology – are generated in the fields of material analysis in biology/chemistry, biotechnology, material science, and robotics. This sensing approach was awarded to the finale of Innovation Radar Prize 2016 in the category 'Excellent Science'. The proposal describes a concrete strategy for targeting a global market of sensor devices. It is complementary to the ASSISI|bf project and allows extending its technological impact.

Coordinator

CYBERTRONICA UG (HAFTUNGSBESCHRANKT) GMBH Germany

Using EIS with microorganisms (yeast *Saccharomyces Cerevisiae*)



anaerobic fermentation
$C_6H_{12}O_6$ -> $2CO_2$ + $2C_2H_5OH$

CO_2 + H_2O -> (H_2CO_3) -> H^+ + HCO^-_3

metabolic products with
Zn^{+2}, Co^{+2}, Mg^{+2} and Mn^{+2}

- using electrochemical impedance spectroscopy
- statistical approach (the same MU system)
- 100 ml containers
- optical/magnetic/thermal excitation
- biological response (e.g. stimulation/inhibition)

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biosensors

MDPI

Article

The Biosensor Based on Measurements of Zymase Activity of Yeast *Saccharomyces Cerevisiae*

Yury Nepomnyashchiy[1], Olga Kernbach[1], Igor Kuksin[1], Andreas Kernbach[1], Timo Dochow[2], Andrew Bobrov[3] and Serge Kernbach[1]

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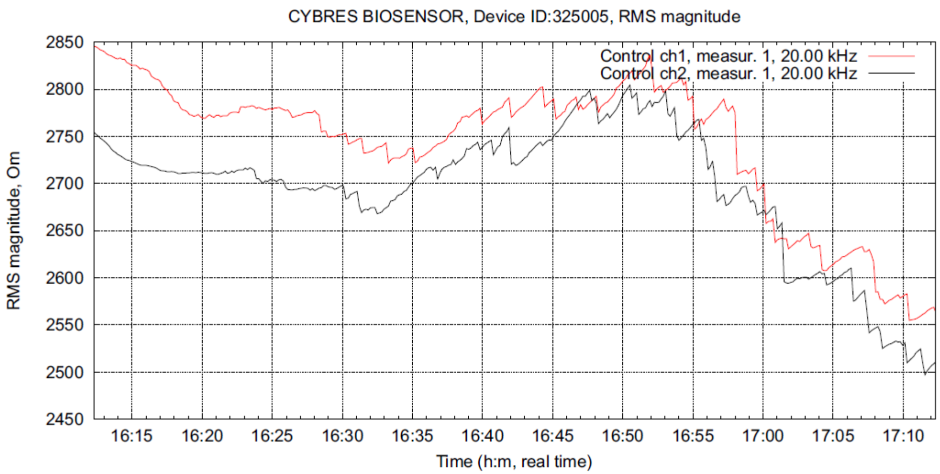
Abstract: This paper describes the bio-hybrid approach for environmental monitoring and estimating quality of water by measuring the zymase activity of yeast *Saccharomyces cerevisiae*. Comparing to bacterial bioluminescence approach, the proposed method has no toxicity, excludes usage of gene-modified microorganisms, and enables low-cost express analysis. Two measurement systems, based on pressure sensing and on electrochemical impedance spectroscopy, have been developed. Results of measurements are compared with each other from the viewpoint of accuracy, reproducibility and usability in field conditions. The performed experiments demonstrated sensitivity of this approach for measuring the quality of drinking water, non-chemical water treatment, and impact of distant environmental stressors.

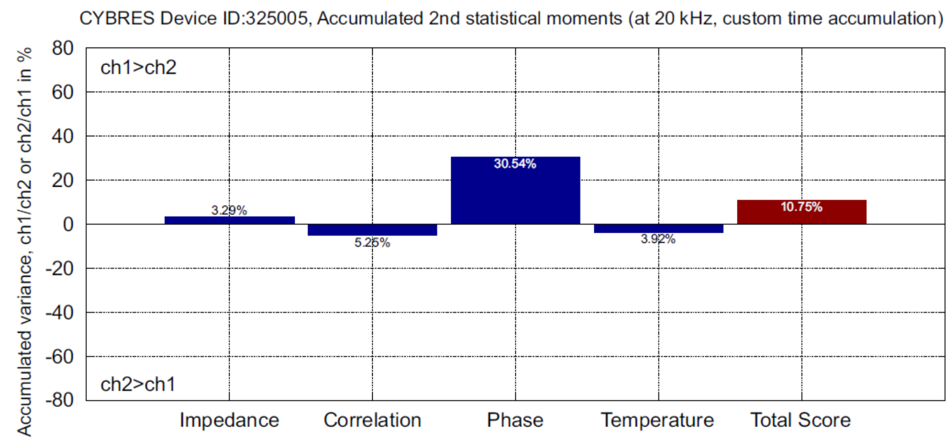
(in submission)

Example of biological EIS analysis

MEMON BIONIC INSTRUMENTS

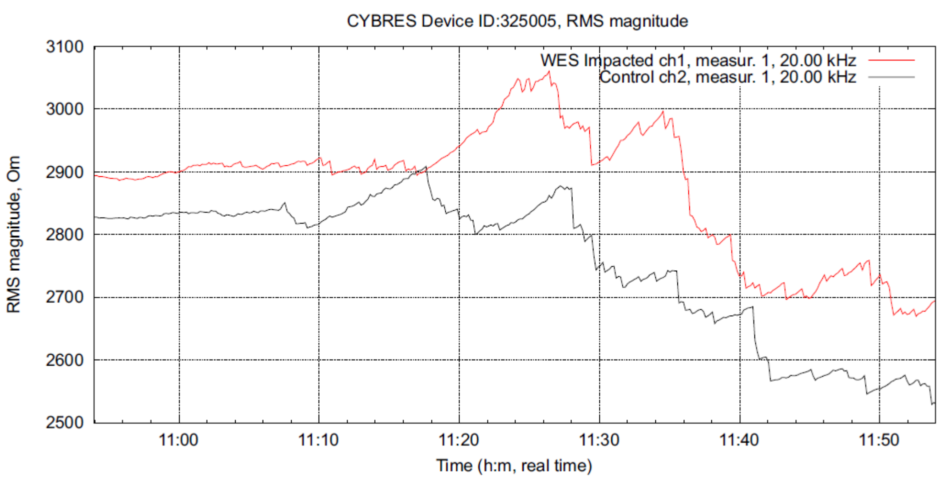


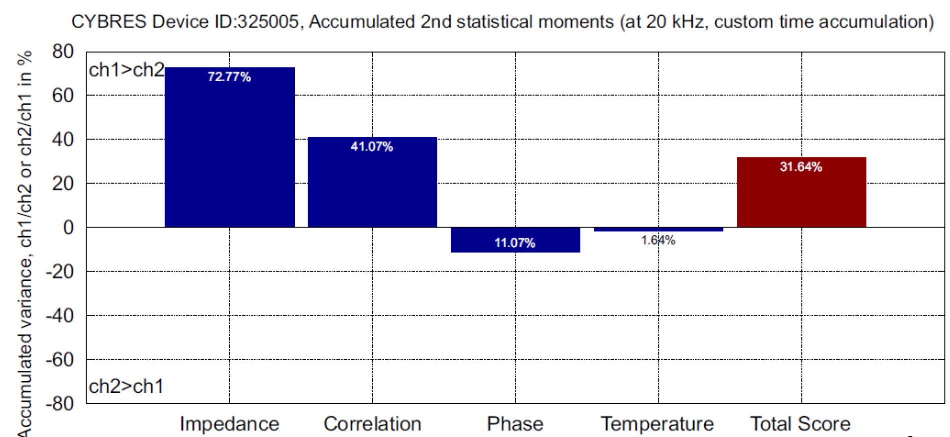
(a)



control

(b)





experiment

CYBRES

Example of biological EIS analysis

Experimental generator of magnetic vector potential (Poynting vector emitter *)

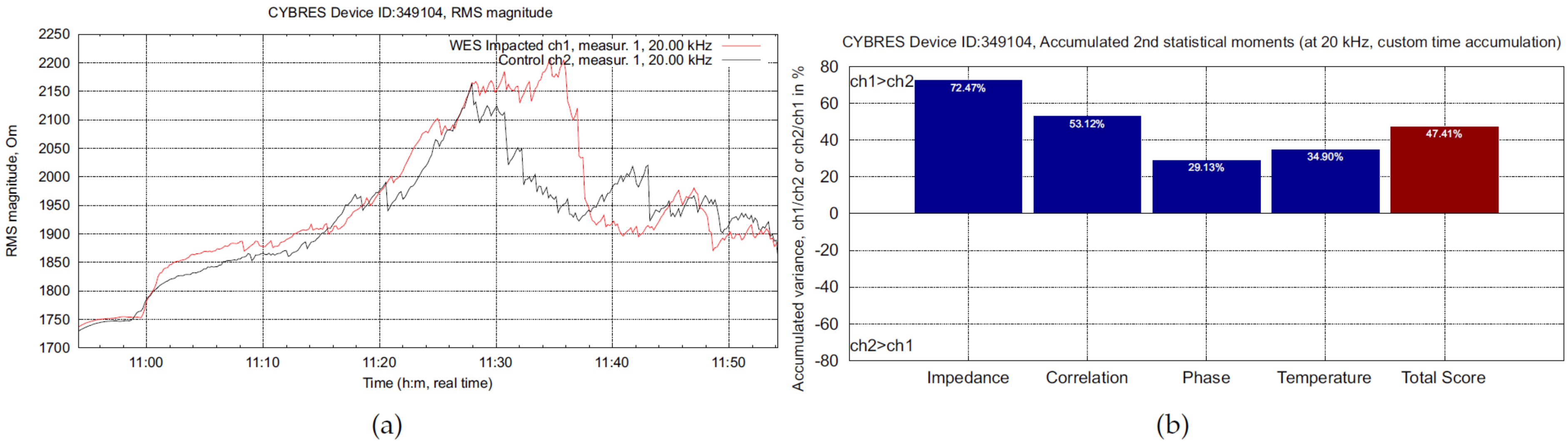


Figure 16. Yeast fermentation dynamics at 20 kHz. Experimental attempt with WES impact (Vector Magnetic Potential) in Ch1: **(a)** RMS magnitude; **(b)** Accumulated variance.

(*) S. Kernbach. Tests of the circular Poynting vector emitter in static E/H fields, IJUS, Issue E2, pages 23-40, 2018

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Conclusion

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1. Non-chemical treatment is enabling technology for many areas
2. Measurement is the key issue for non-chemical treatment
3. No only complex laboratory methods -> simplicity of measurements for end-users or on a factory (production) scale

4. Based on ionic dynamics and statistical moments
5. Water and microoganisms for electrochemical and biological characterization of non-chemical treatment

6. Available on the market