THE 15TH RUSSIAN-CHINESE WORKSHOP
ON SPACE WEATHER

Electromagnetic ELF response of the near-Earth space on man-made activity

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ZEVS Installation

Location: the Kola Peninsula, near Murmansk, on the Baltic crystalline shield.

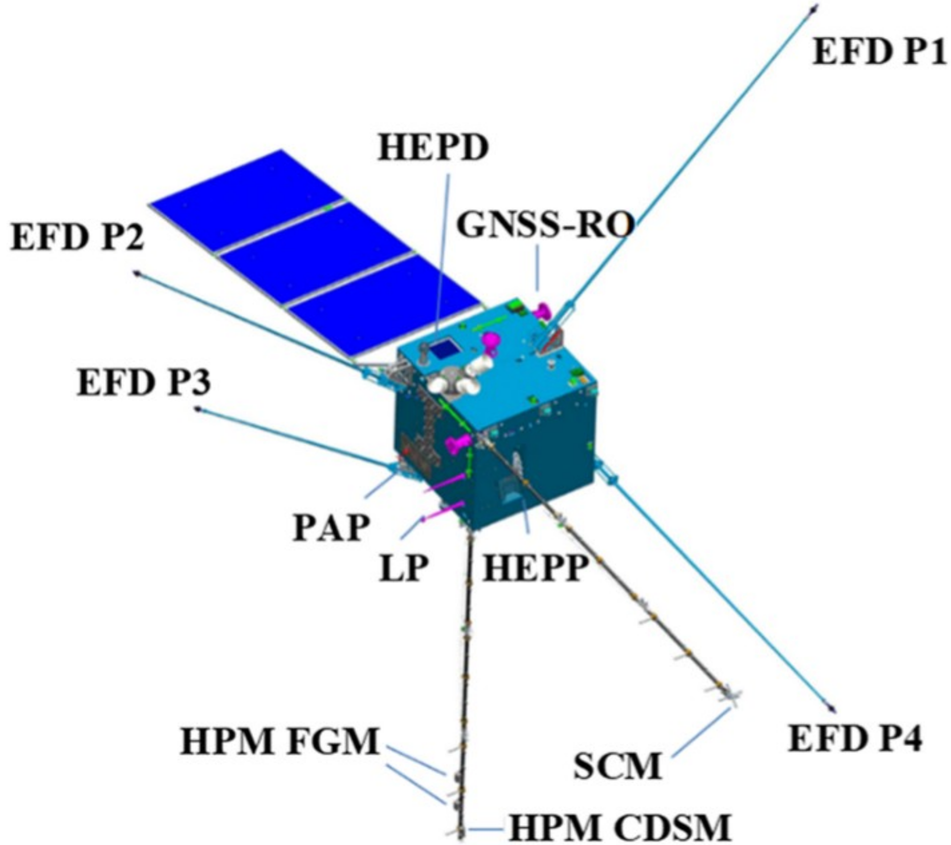
Structure: two horizontal aerials 60 km long, generators, grounding wells.

Current intensity is 200-300 A.

Total power is up to 2.5 MW

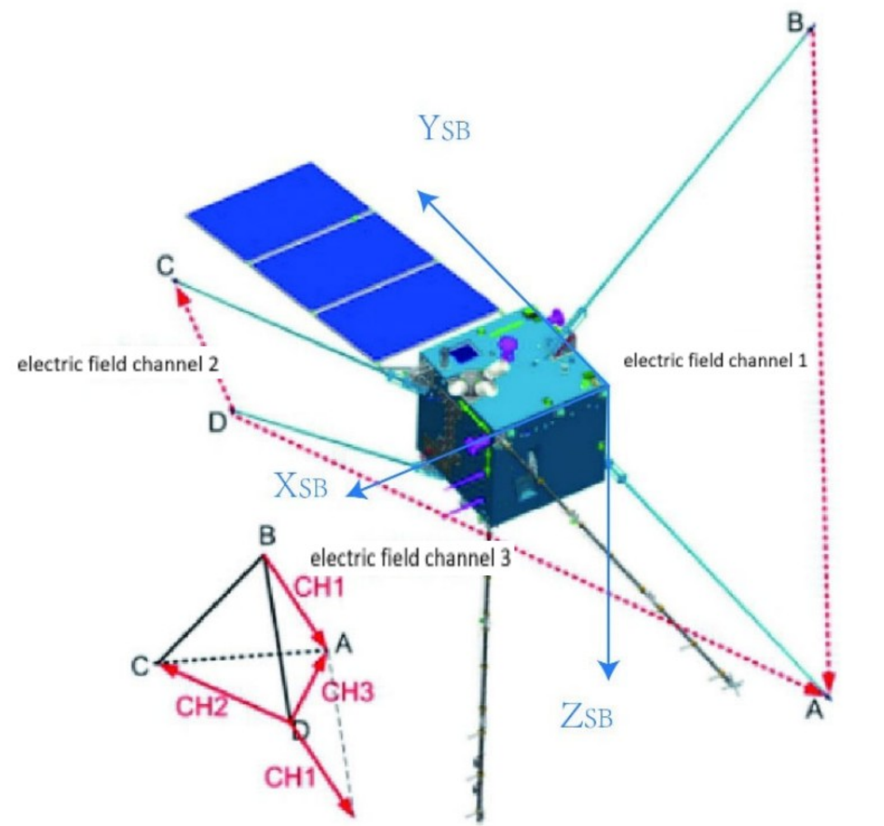
Radiated power is up to 5 W.

Signal parameters: 82 Hz, λ = 3 658.5 km



CSES (ZH-1) satellite
www.leos.ac.cnz

The first China Seismo-Electromagnetic Satellite (CSES) was launched on February 2018 into a sun-synchronous polar orbit at an altitude 500 km with an inclination of 97 deg and period of 95 min.



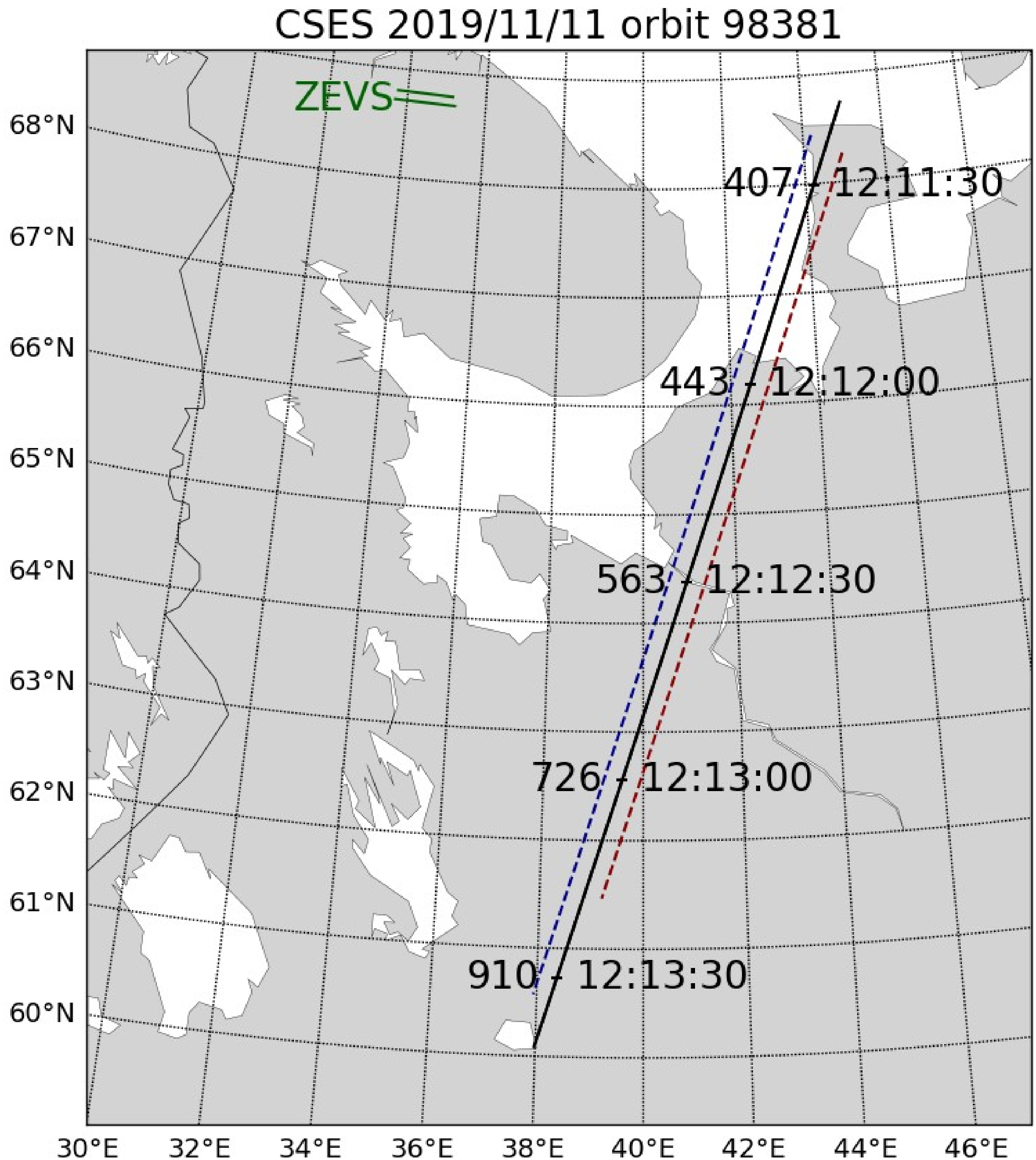
- **Electric Field Detector** (EFD) measures the electric potentials of 4 spherical sensors and derives the electric field in the frequency range between DC and 3.5MHz.
- **Search-coil magnetometer** (SCM) measures 3-component variations of the magnetic field in the frequency range from 10Hz to 20kHz.

Detection of ZEVS signal on 2019/11/11

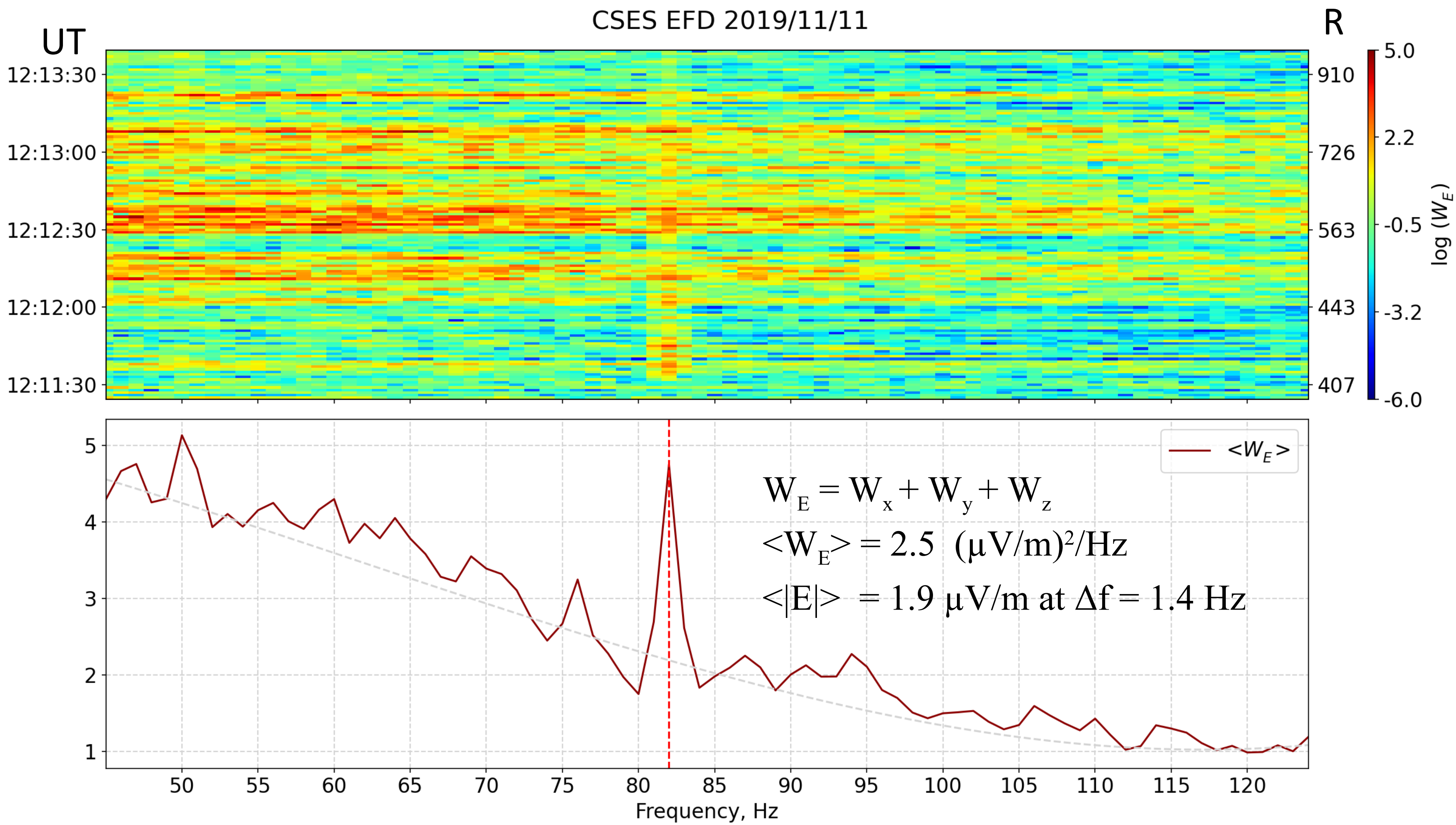
CSES flight path is depicted in black.

EFD/SCM measurement range is outlined by blue/ maroon dashes.

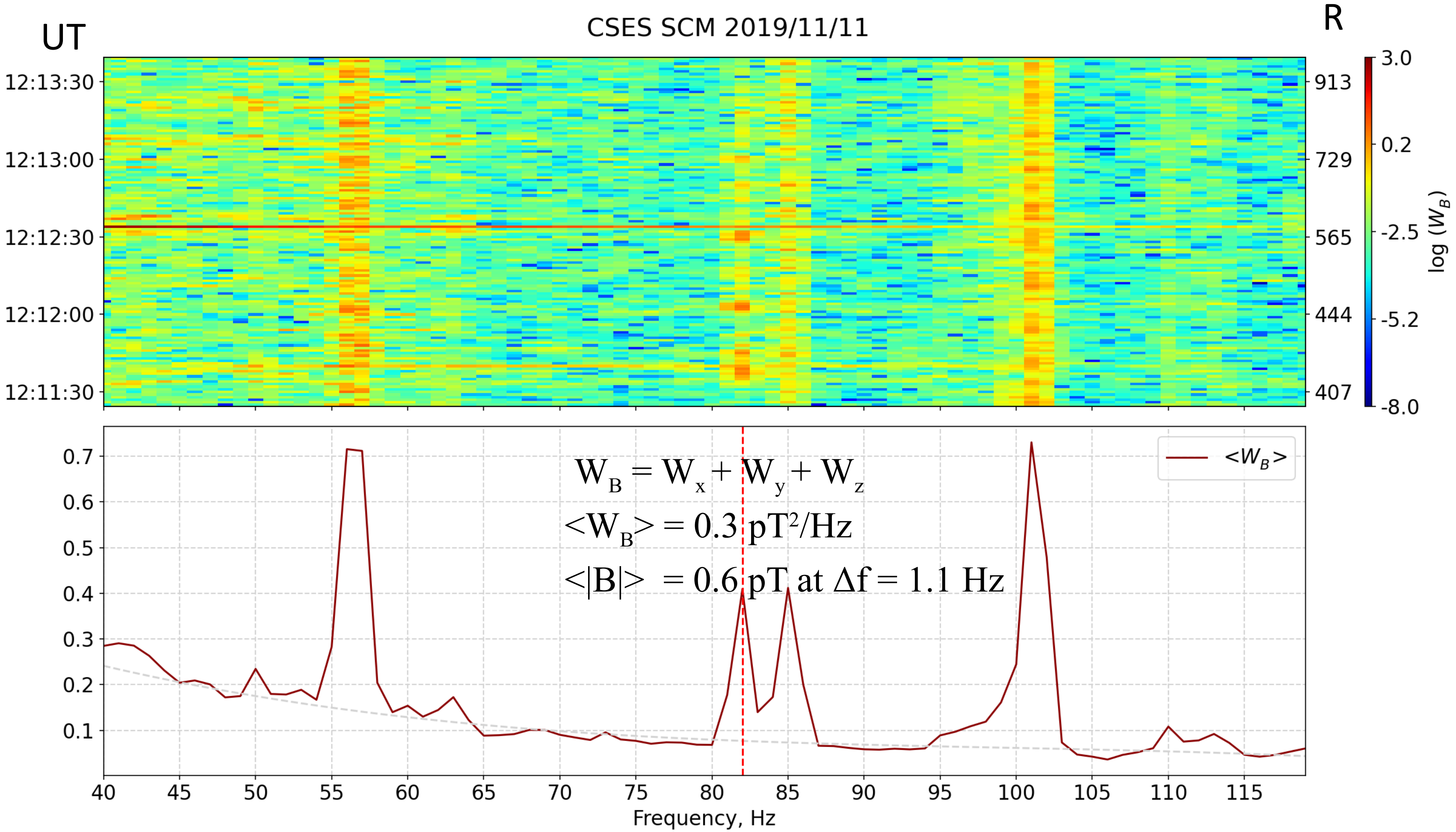
Signal 82 Hz was detected from 12:11:30 to 12:13:30 UT (+3LT), at distance from 400 to 900 km from the source.



Electric Component by EFD measurements



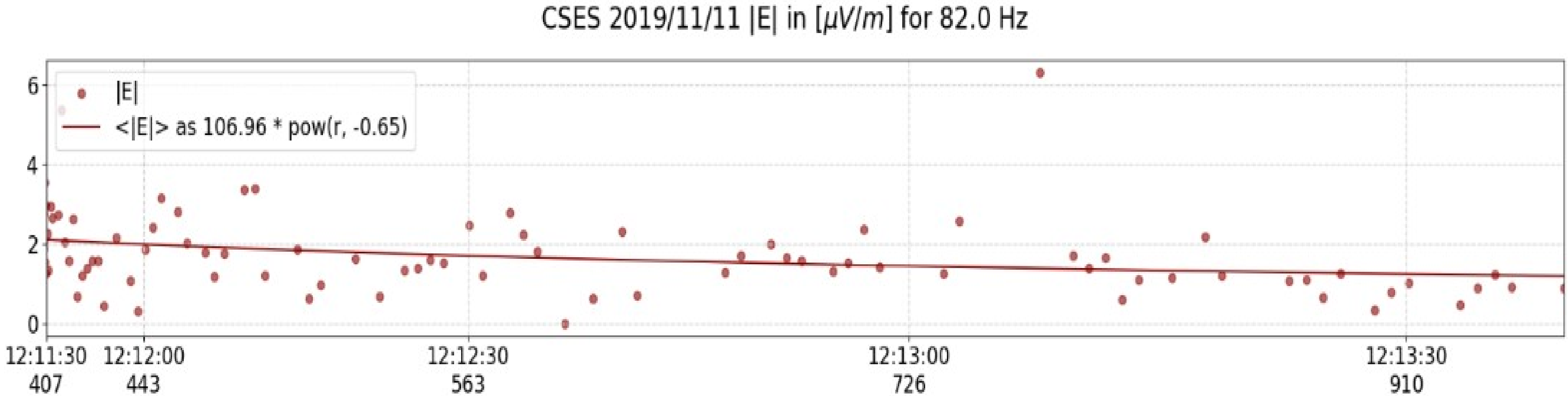
Magnetic Component by SCM measurements



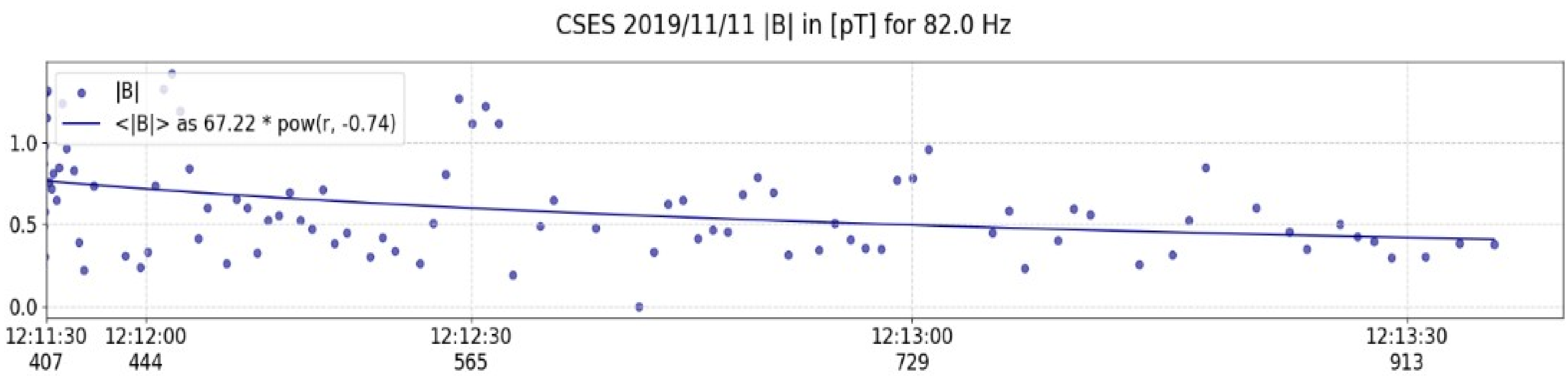
Magnetic field records are more contaminated by interference

Signal Amplitude Attenuation

Electric component amplitude attenuation as function of distance R from the transmitter
$E(R) \sim R^S \rightarrow S = -0.65$



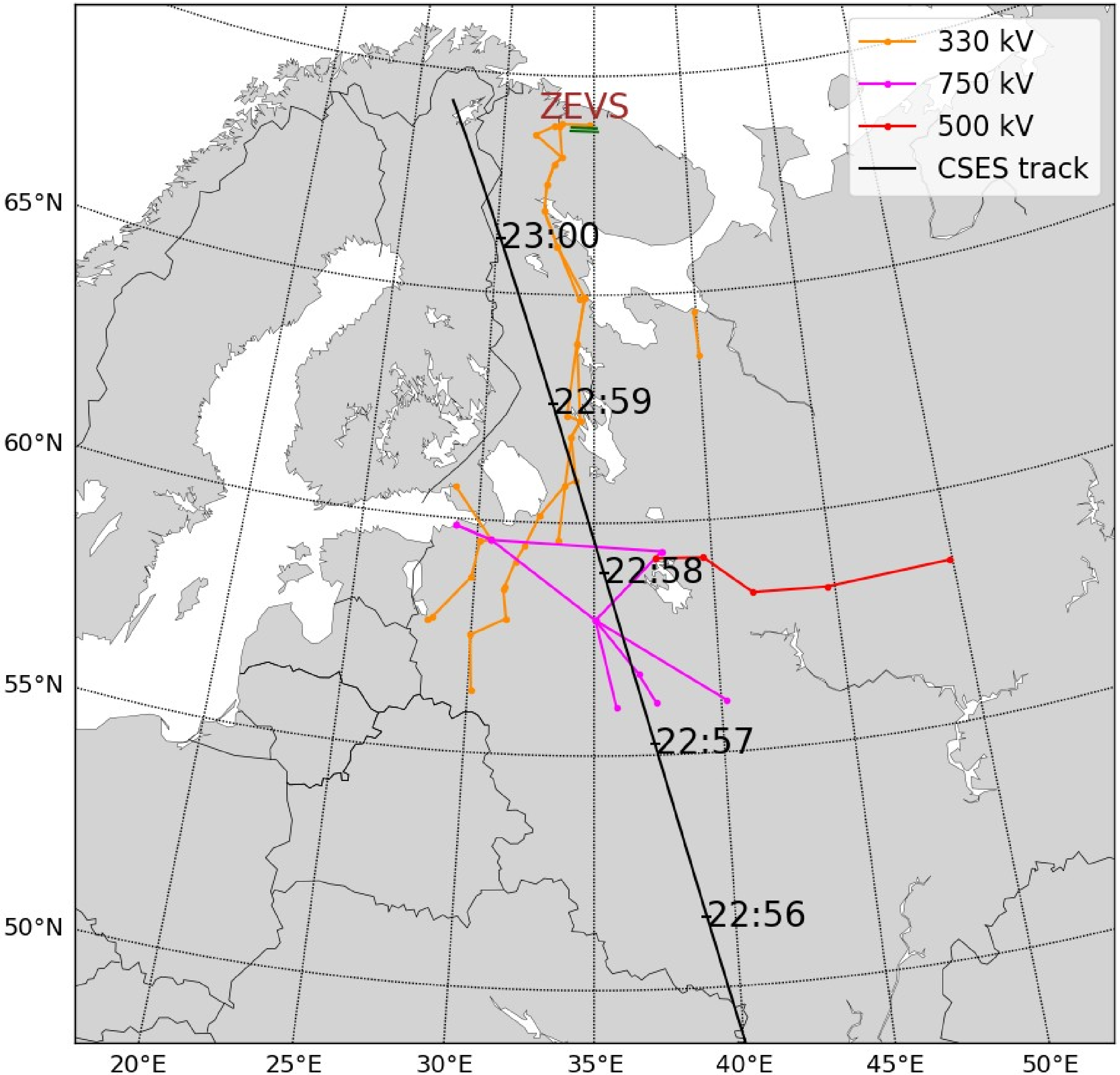
The same analysis of magnetic component amplitude gives: $B(R) \sim R^S \rightarrow S = -0.74$



Electric Power Transportation System of the North-West of the Russian Federation

- “**<u>Northern Transit</u>**” is 330 kV three-phase industrial power transmission line running through the Kola Peninsula. It comprises of four chains. Its total length exceeds 750 km.
- <u>Perfectly-balanced</u> power line: voltages and currents of each phase have the same amplitude, and phase shift is 120°.
- <u>Unbalanced</u> line becomes a source of 50 Hz and harmonics radiation.

Simultaneous detection of ELF emissions from ZEVS and Northern Transit on March 21, 2022



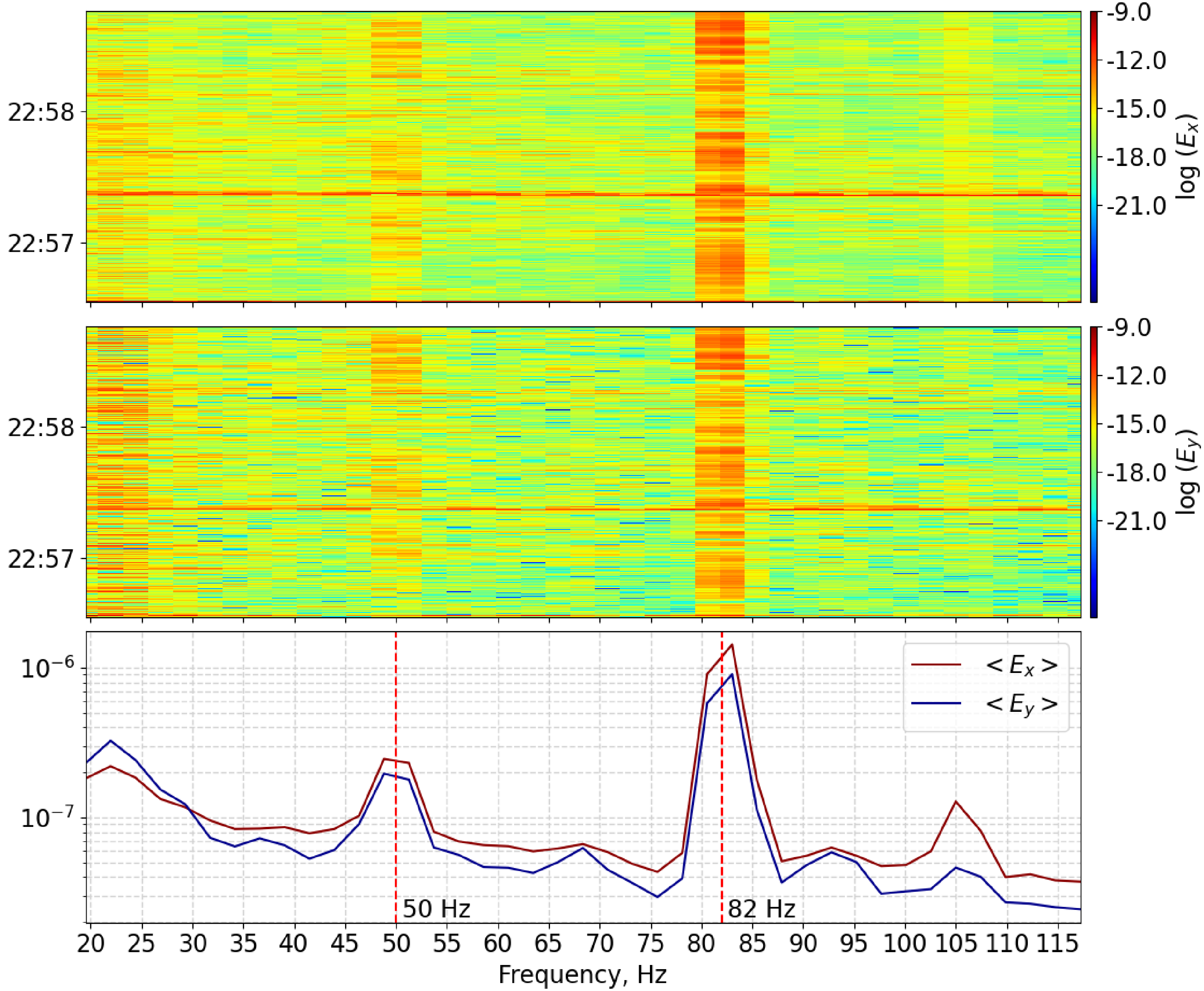
330 kV Northern Transit is depicted orange.

Powerlines of Leningradskaya NPP are depicted violet.

Powerline of Severstal Holding are depicted red.

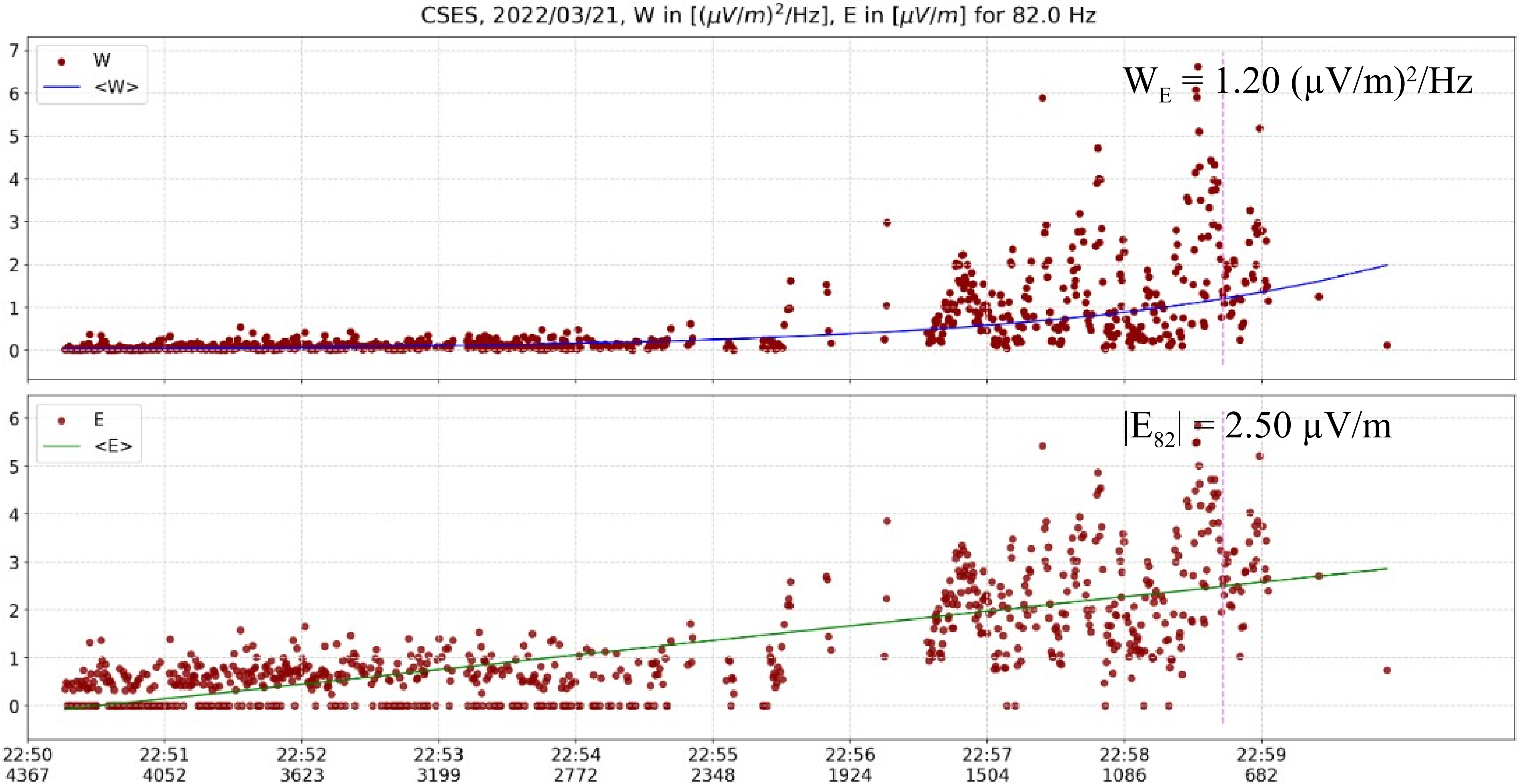
Signals at 50 and 82 Hz are observed from 22:56:00 UT (+3LT) to 22:59:30 UT, within high latitude range from 55 to 65 degrees North.

Signals at 50 and 82 Hz are evident in X and Y components of electric field .

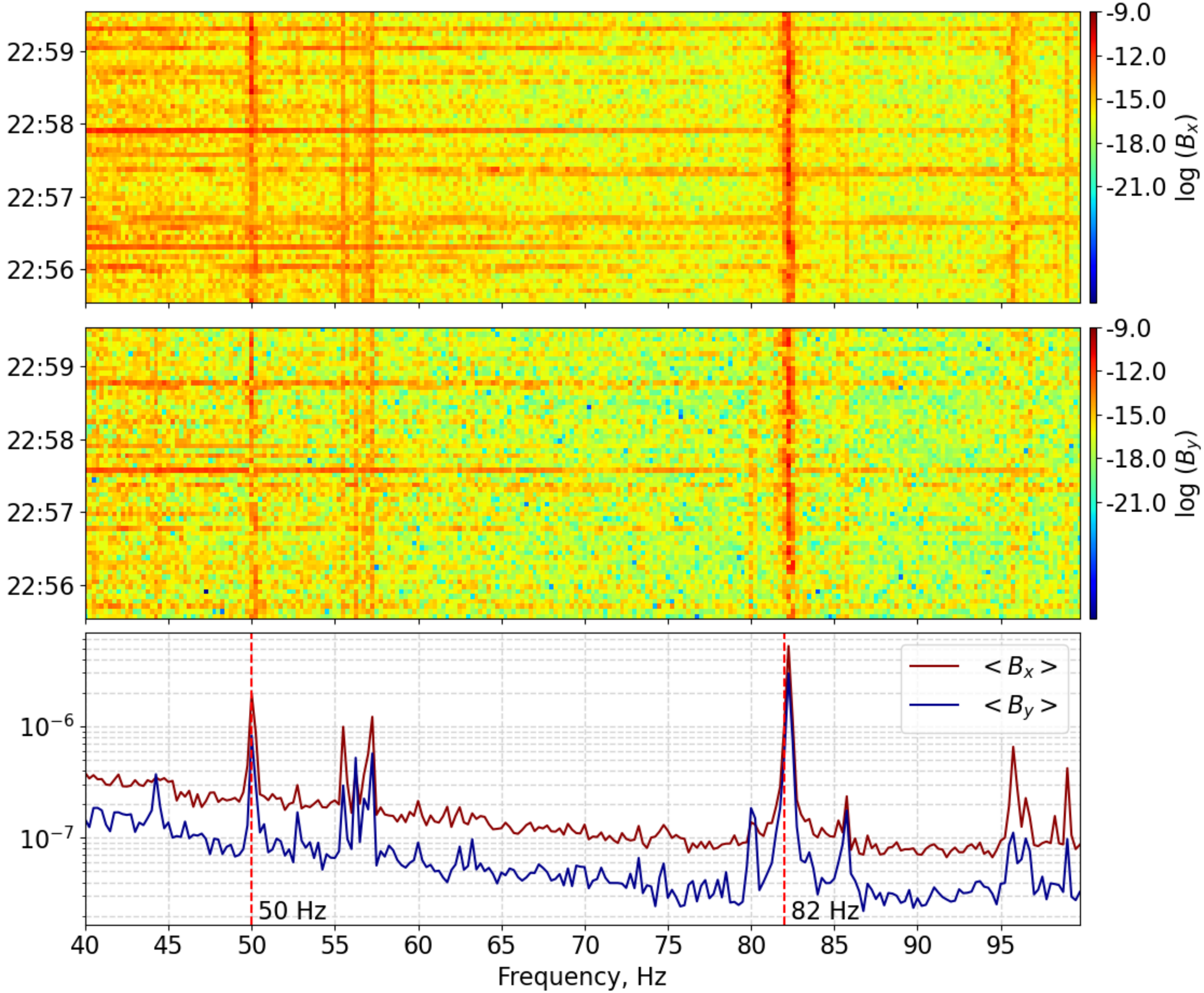


Attenuation of electric component of 82 Hz signal measured by EFD

In this event, we observe strong 82 signal for about 2000 km from the source. Violet dashed line mark R = 800 km from the source and the corresponding values of W_E and E are given.

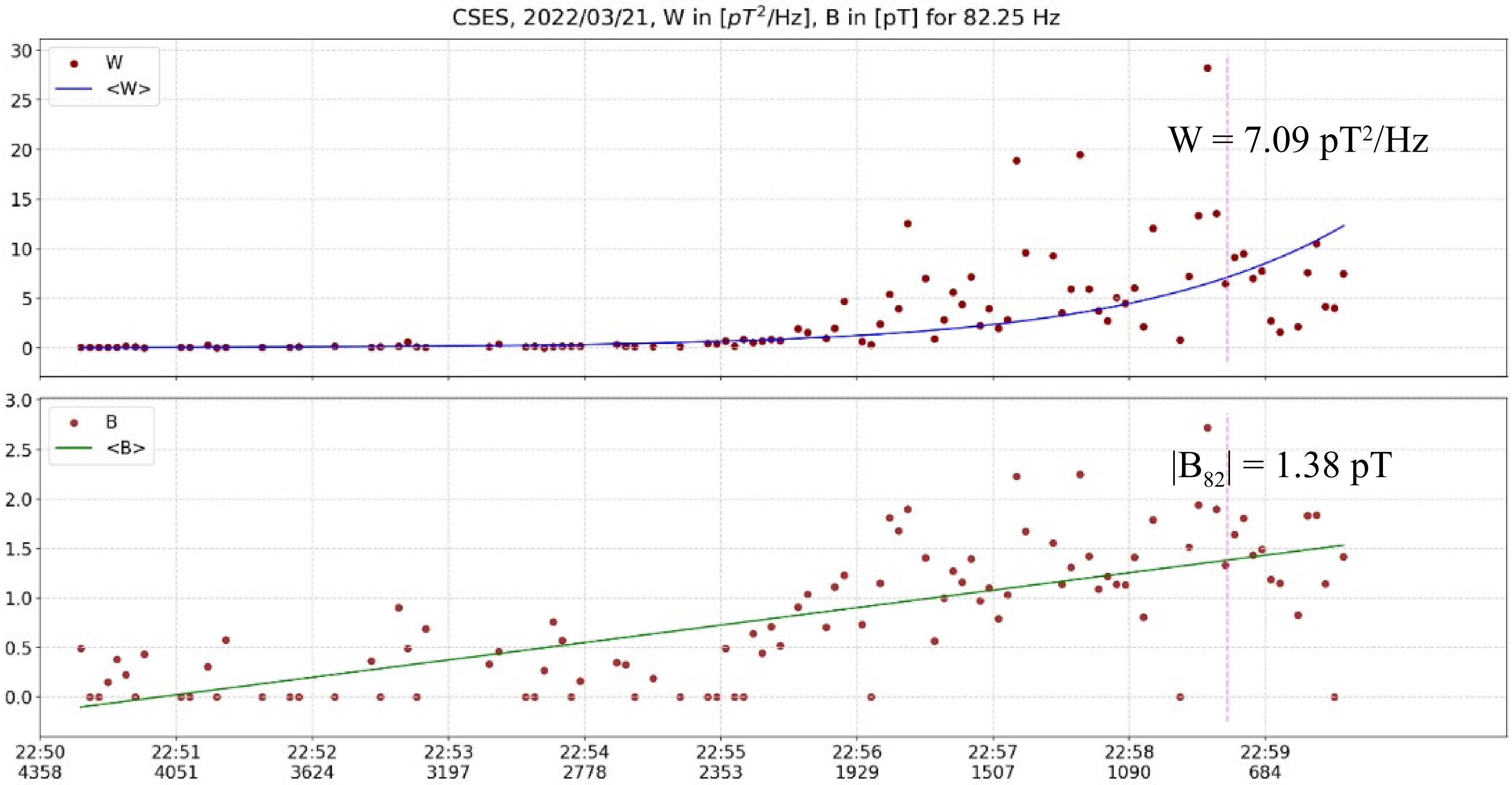


Signals at 50 and 82 Hz are also distinguishable in X and Y components of magnetic field.

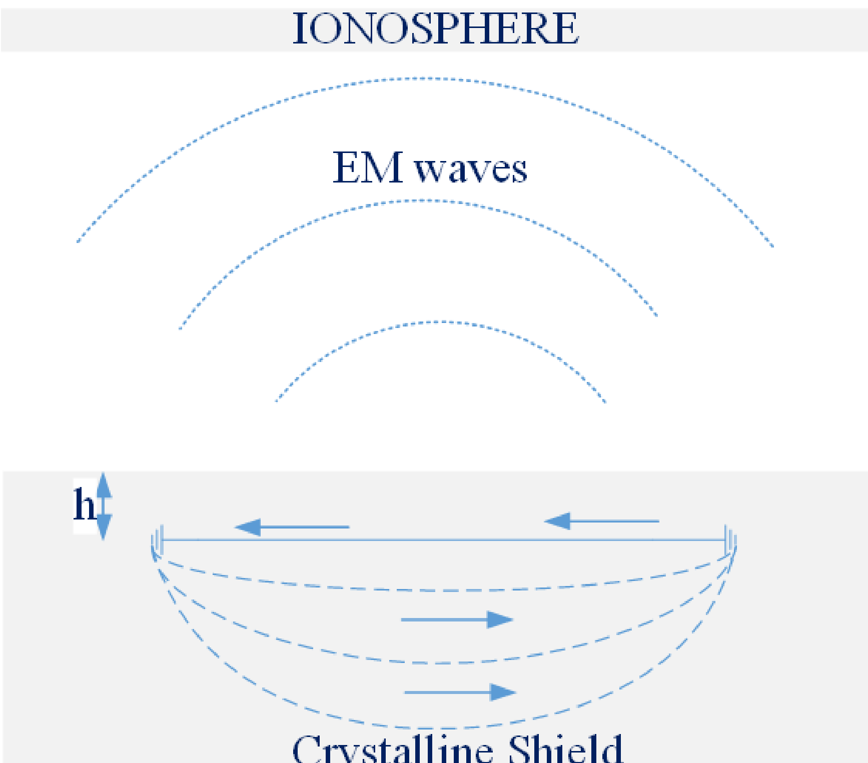


Attenuation of magnetic component of 82 Hz signal measured by SCM

Magnetic component is observed at slightly shifted frequency 82.0-82.25, and also features slow attenuation, so the signal is visible up to 2000 km from the source. Violet dashed line mark R = 800 km from the source and the corresponding values of W_B and B are given.



Model of ELF wave excitation in the ionosphere by a horizontal current of a finite length



Fedorov E.N. et al., Radiophysics and Quantum Electronics, Vol. 65, No. 9, 2023.

- The recently elaborated numerical model calculates the e/m field in entire system ground-atmosphere-ionosphere by a horizontal grounded aerial of finite length.
- To account for spreading currents in the ground (conductivity 10^{-5} S/m), the source is formally immersed into the ground.

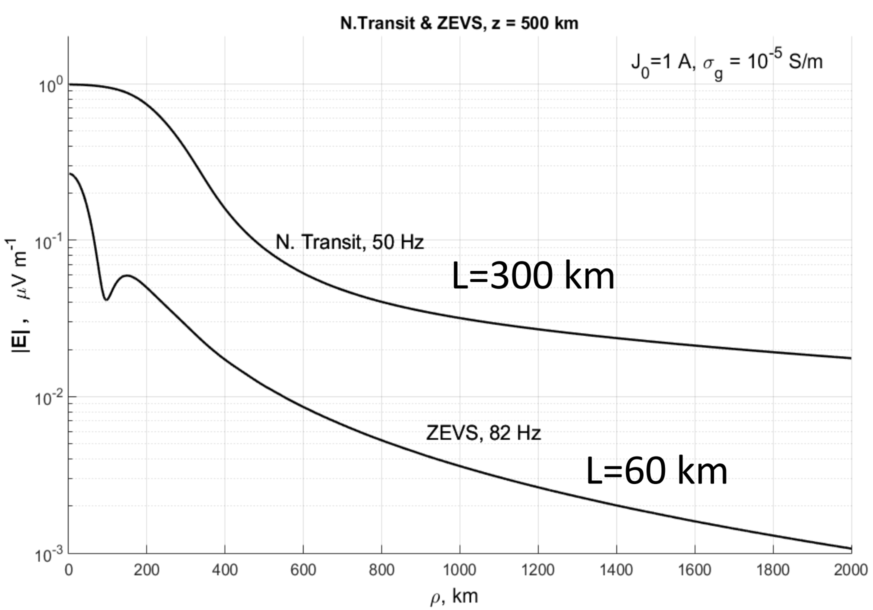
  The atmosphere conductivity increases exponentially with altitude.

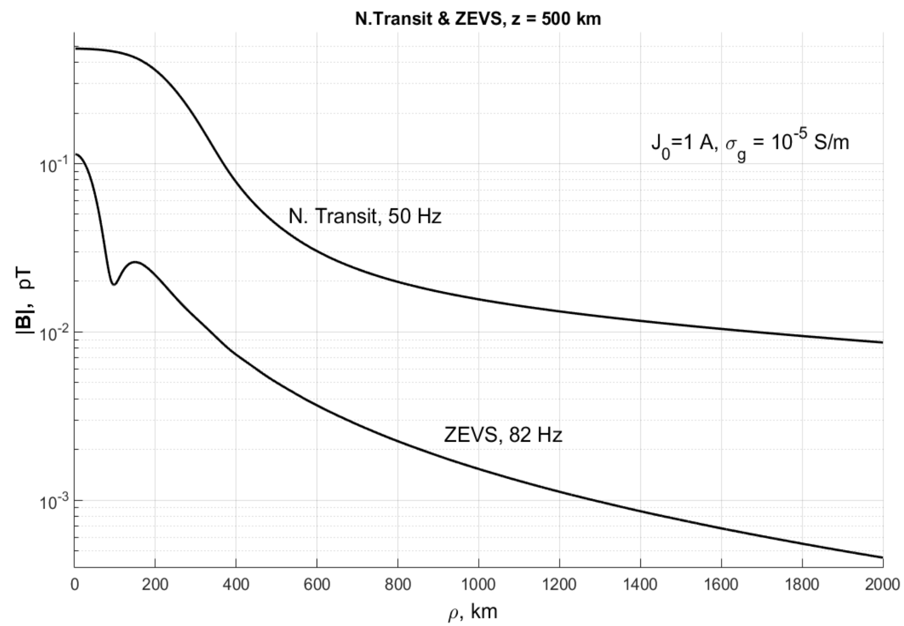
  The parameters of a vertically inhomogeneous ionosphere are determined from the IRI model.

  The geomagnetic field is vertical I=90°.

  To overcome the azimuthal asymmetry of the problem, a mathematical formalism based on the introduction of field potentials has been used. The fields created by individual horizontal dipoles are numerically summed up.
- The calculated fields are normalized by the value of the source current J = 1 A.

Spatial structure of E and B field for ZEVS (60 km long) and Northern Transit (300 km long) sources normalized to current $J_0 = 1$ A





Maximal E-field amplitude above the source:

$|E_{50}| \approx 1.0$ μV/m and $|E_{82}| \approx 0.15$ μV/m

Slow attenuation: signal decreases 10 times at a distance ≈ 850 km from the source.

Maximal B-field amplitude above the source:

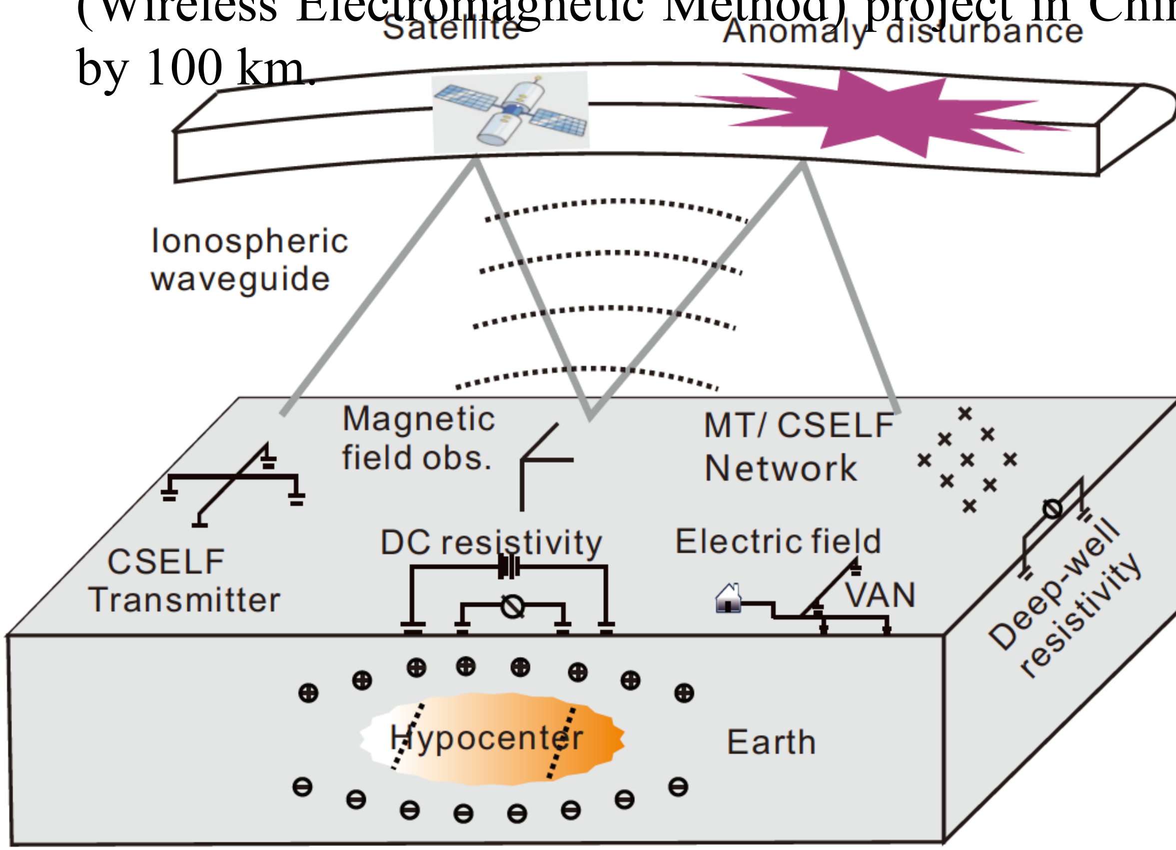
$|B_{50}| \approx 3.5$ pT and $|B_{82}| \approx 0.11$ pT

Slow attenuation: signal decreases 10 times at a distance ≈ 810 km from the source.

Further Research Possibilities

It is possible to conduct up-to-date active experiments using large-scale horizontal antennas. Existing installations can excite artificial ULF radiation in the ionosphere:

- FENICS facility comprising 100-km line at Kola Peninsula in Russia;
- CSELF (Control Source Extremely Low Frequency) system and WEM (Wireless Electromagnetic Method) project in China, comprising 2 antennae 60 by 100 km.



Thanks to resonant wave-particle interaction, ULF e/m waves (fractions of Hz), can initiate precipitation of electrons from the radiation belt into the atmosphere and thus reduce fluxes of "killer" electrons down to the safe level for satellite electronics.

Conclusions

- ZEVS signal was detected by CSES satellite at up to **900 km** from the source on 2019/11/11 and up to **2000 km** on 2022/03/21.
- The driving current within the ZEVS installation (~100 A) is sufficient excite comparatively string 82 Hz signal in the upper ionosphere.
- Power line Northern Transit with unbalanced current ~ 1-2 A is capable to produce 50 Hz emission detected by CSES.
- E/M environment of the Earth is strongly influenced by **industrial activity**, not just natural processes. Intensity of the power line emissions in the near-Earth space environment was noticeably increased after the introduction of super-high-voltage power lines, and gradually increases over time.
- Industrial development, especially over the industrialized areas, stimulates further electromagnetic “pollution” of the near-Earth space environment by the ever-growing network of the power lines.

What consequences can be expected from the increasing "pollution" of near–Earth space environment by power line radiation ?

Thank you for attention!

Contact us if any questions:

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