Анализ низкочастотных электромагнитных шумов для оценки пылевой динамики атмосфера Марса

Analysis of low-frequency electromagnetic noise to assess the dust dynamics of the Martian atmosphere

Mohamad Essam Abdelaal

[1]Moscow Institute of Physics and Technology,

[2]Space Research Institute of the Russian Academy of Sciences

(mohamad.essam@phystech.edu)

M. E. Abdelaal[1,2], I.V. Dokuchaev[2], A. N. Lyash[2] ,I. A. Kuznetsov[2], G. G. Dolnikov2,

A. E. Dubov[2] and A. V. Zakharov[2]

Mars

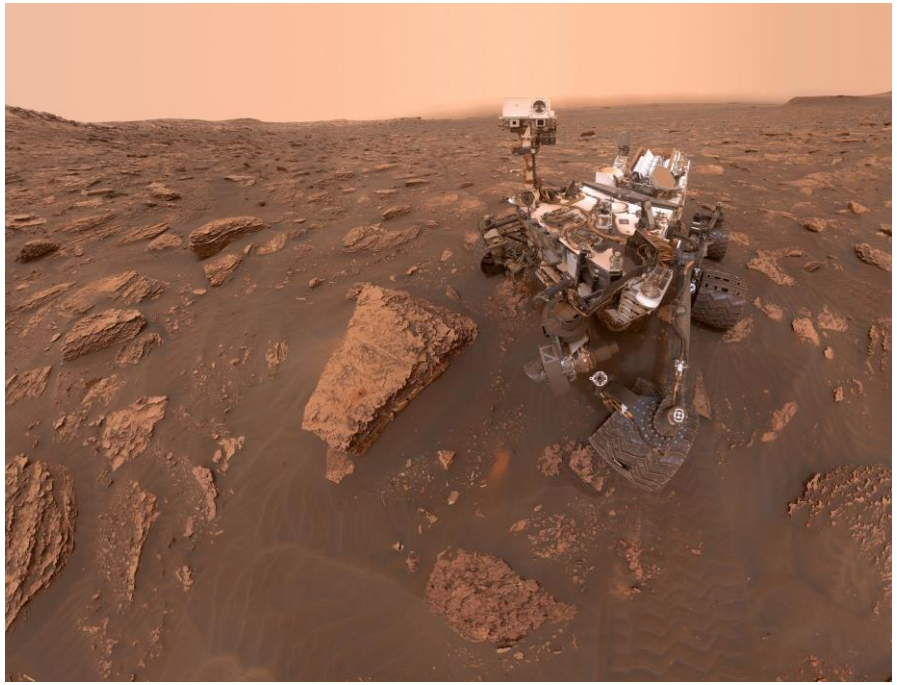
Data from the Viking landers raised the possibility that Martian dust storms might be electrically active like Earth's thunderstorms and thus, might be a source of reactive chemistry.

https://mars.nasa.gov/resources/5307/the-serpent-dust-devil-of-mars/

Mars without a dust storm in June 2001 (on left) and with a global dust storm in July 2001 (on right), as seen by Mars Global Surveyor

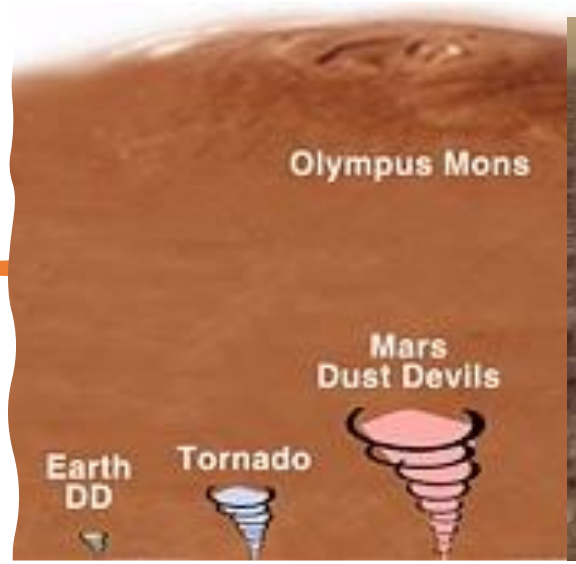
Electric Dust Storms on Mars

Electric activity in Martian dust storms has important implications for Mars science as It affects atmospheric chemistry, habitability and preparations for human exploration.



https://www.nasa.gov/vision/universe/solarsystem/mars_soil_chem.html

Dust Devils



https://mars.nasa.gov/resources/5307/the-serpent-dust-devil-of-mars/

Stretched color version of a movie of a huge “gust lifting” event taken by the Navigation Camera (Navcam) on sol 117. Images are 14 seconds apart. Credit: NASA/Caltech-JPL/SS

The Electric Dust Devil

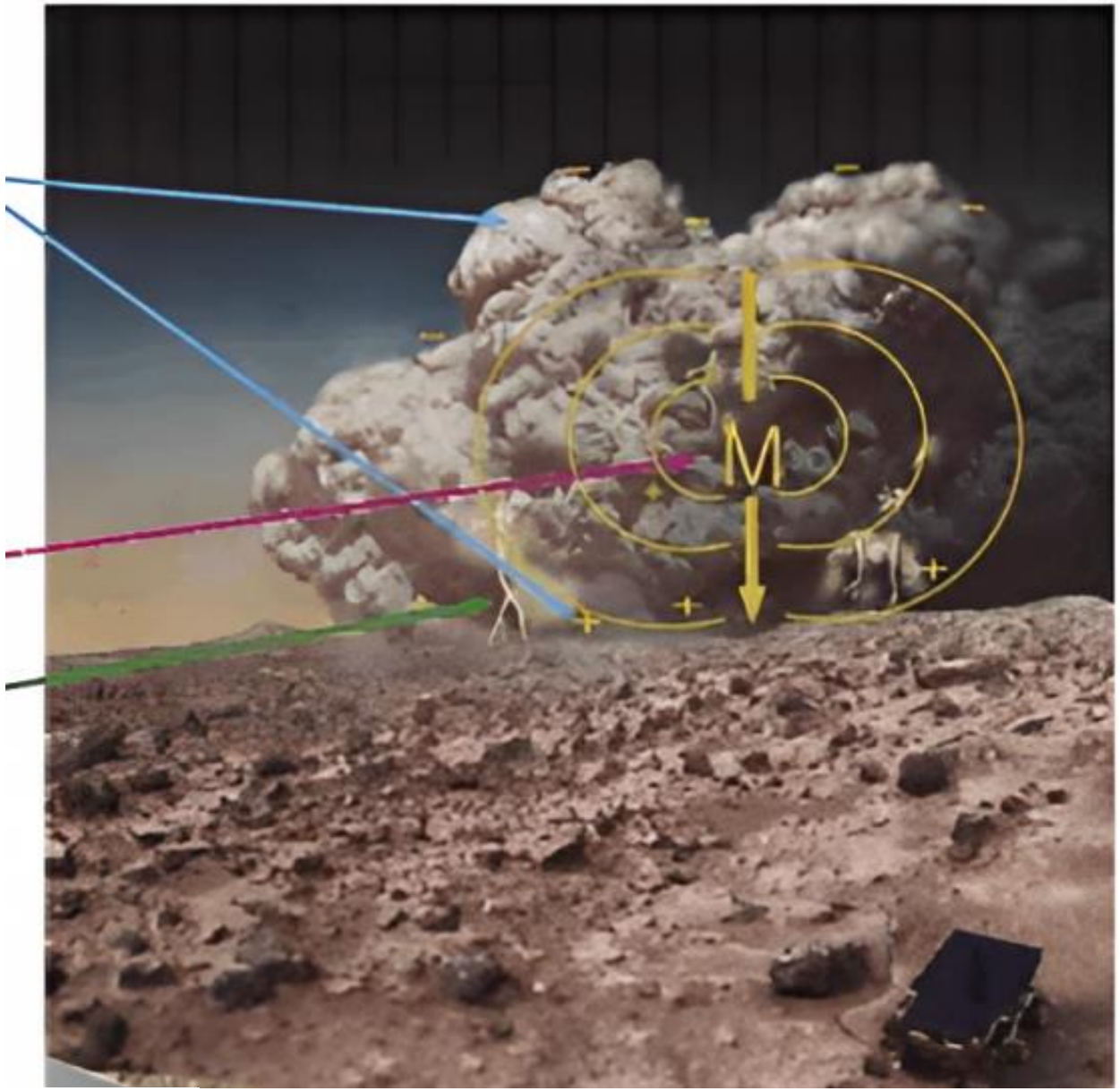
- **Triboelectric interactions light grains (-) charged, Heavy grains (+) charged.**

- **Light grains blown upward in convective process – charge separation**

- **Create electric dipole moment M, and Dipolar electric field**

- **Swirling grains = change in moment**

- **Terrestrial devils we see:**
  - **DC E-Field from M**
  - **Radio emission from grains swirling**
  - **Inducted potential on surfaces**



$$-\varepsilon_0 \frac{dE}{dt} = -J_{\text{tribo}} + J_{\text{diss}} = -n_{\text{dust}} q_{\text{dust}} v_{\text{dust}} + \left[\sigma E + n_0 \exp(\alpha_T d) e \mu_e E\right]$$

Harrison et al 2016

An artist's impression of an electrified dust devil at Mars (from Farrell et al. 2004)

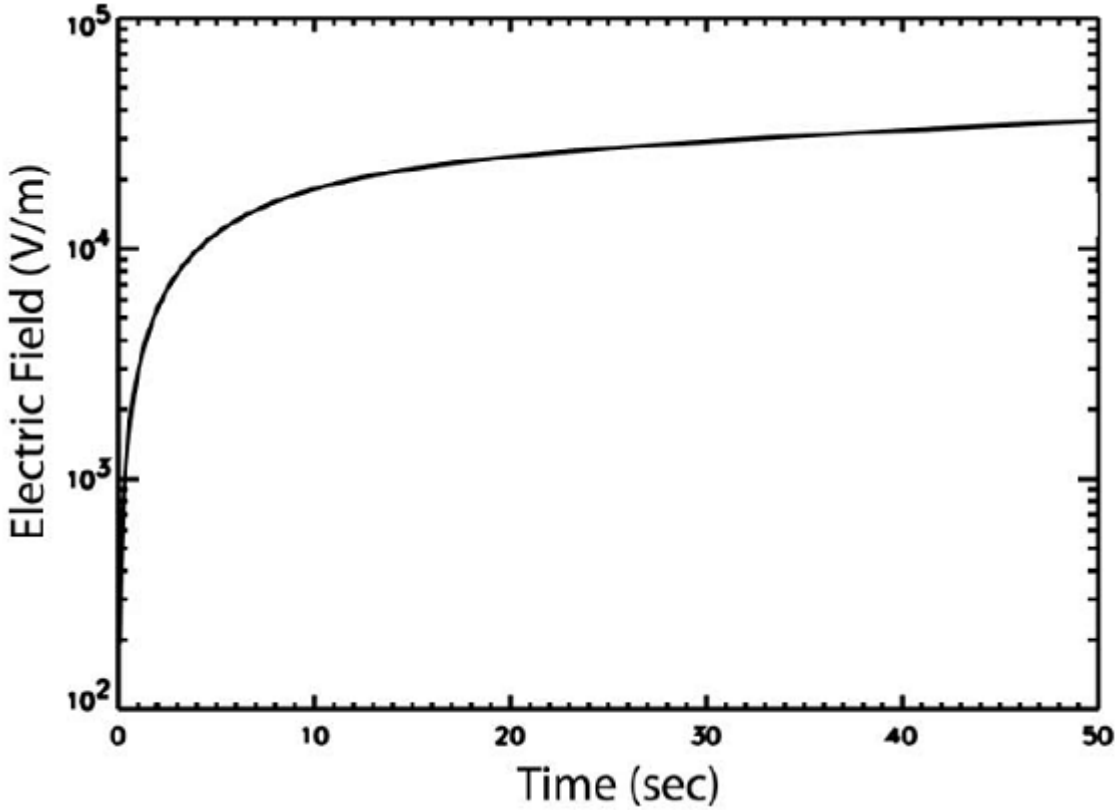


Fig. 1. The evolution of the electric field strength E in a dust storm at a wind speed of 7 m/s (Farrell et al., 2006).

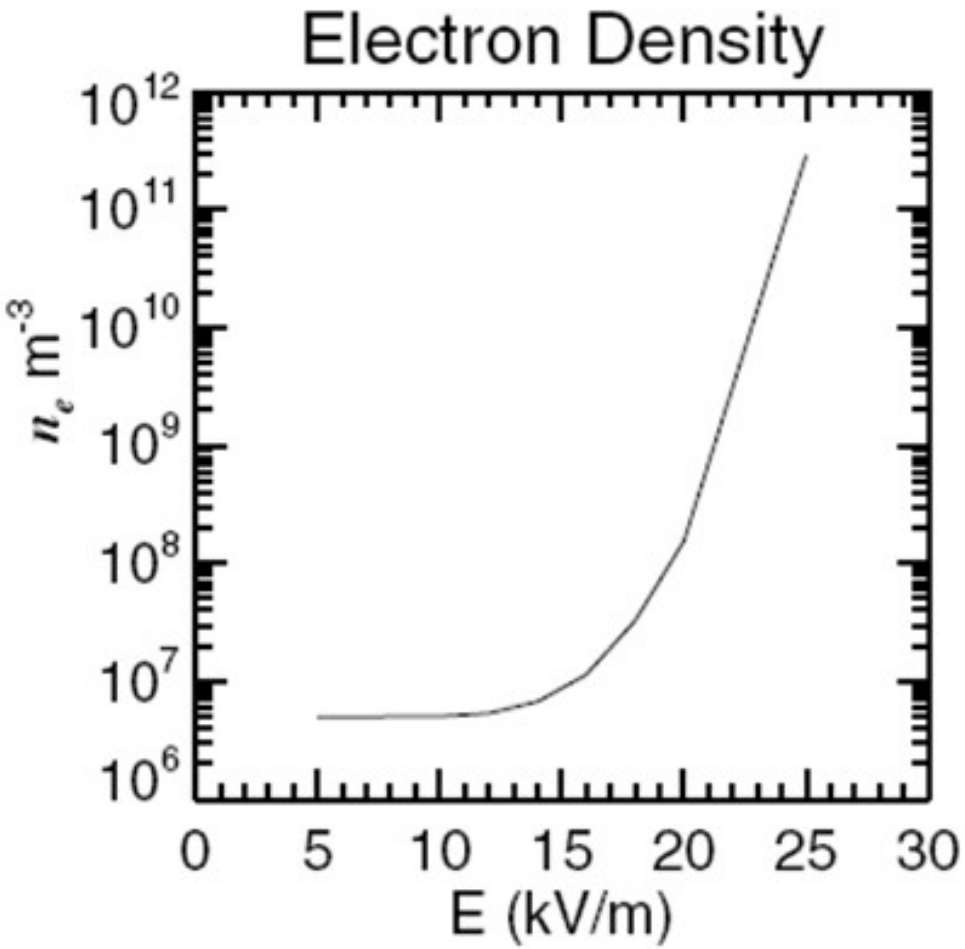
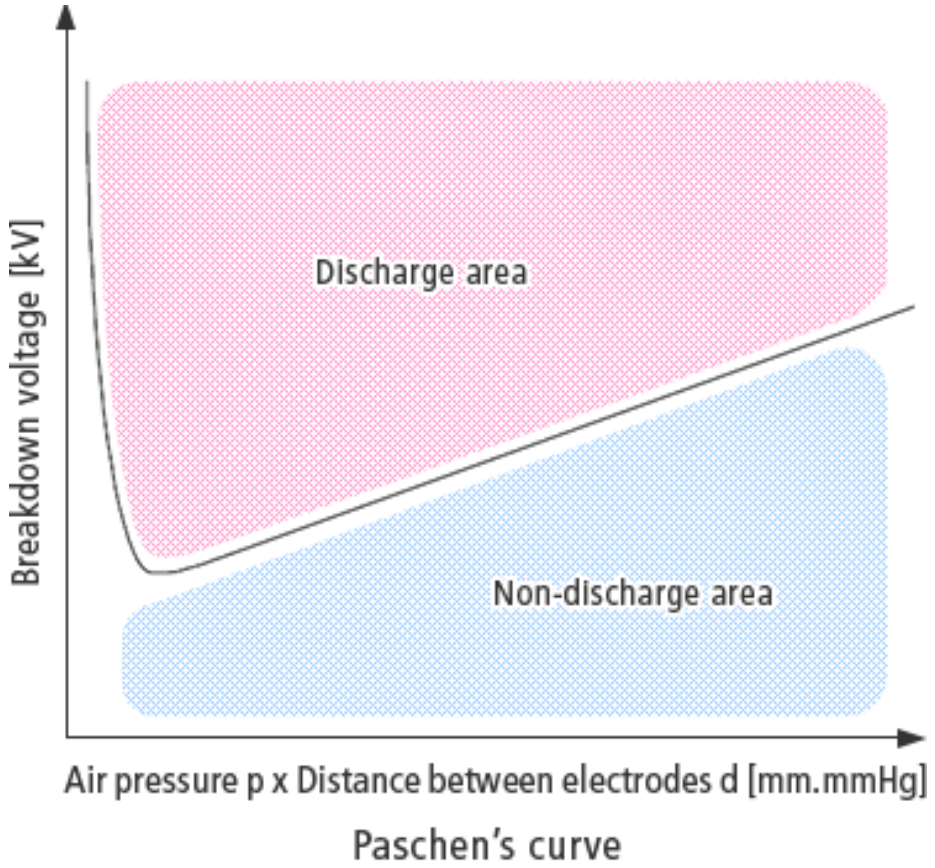


Fig.2. Electron concentration near the surface of Mars as a function of electric field magnitude during a dust storm (Delory et al., 2006)

Electromagnetic Radiation

Charged dust particles, constantly present in the atmosphere of Mars, can be sources of electromagnetic radiation. The nature of these radiations is associated with electrical discharges that can be generated as a result of the triboelectric effect at the surface during the saltation of dust particles and their ionization in the atmosphere. Such processes are most active during the dynamics of dust particles during periods of dust storms and in the areas of dust vortices.

The sources of these signals, which are related to electrical activity in the atmosphere, are particularly important because they can affect the atmospheric composition, the ionospheric structure, and radio wave propagation on the planet.



Paschen's curve

Why Electromagnetic Investigation on Mars?

Examining the parameters of the Martian environment:

- Investigating the dynamics of dust particles in the Martian atmosphere
- Investigating the electrical conductivity of the Martian atmosphere as well as the properties of the near-surface electric field.
- Registering the electromagnetic radiation in order to investigate the nature and circumstances of atmospheric electricity.

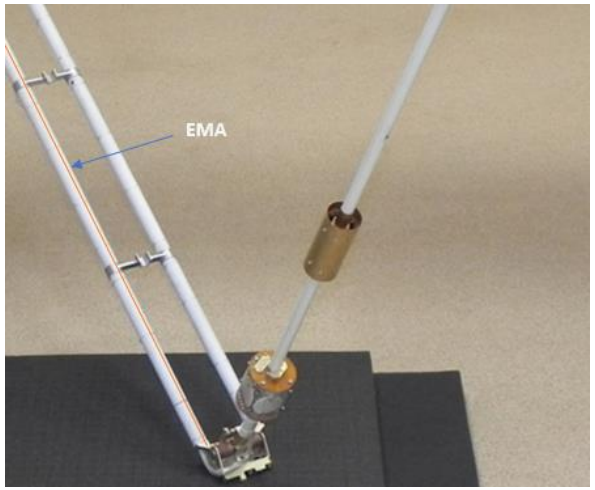
  Furthermore, such electromagnetic signals can be used for a variety of applications, such as surveying Mars' subsurface or analyzing the impact of space weather on the Martian ionosphere. Because ELF waves propagate over very long distances, single-station recordings can be used to investigate the properties of the entire globe.

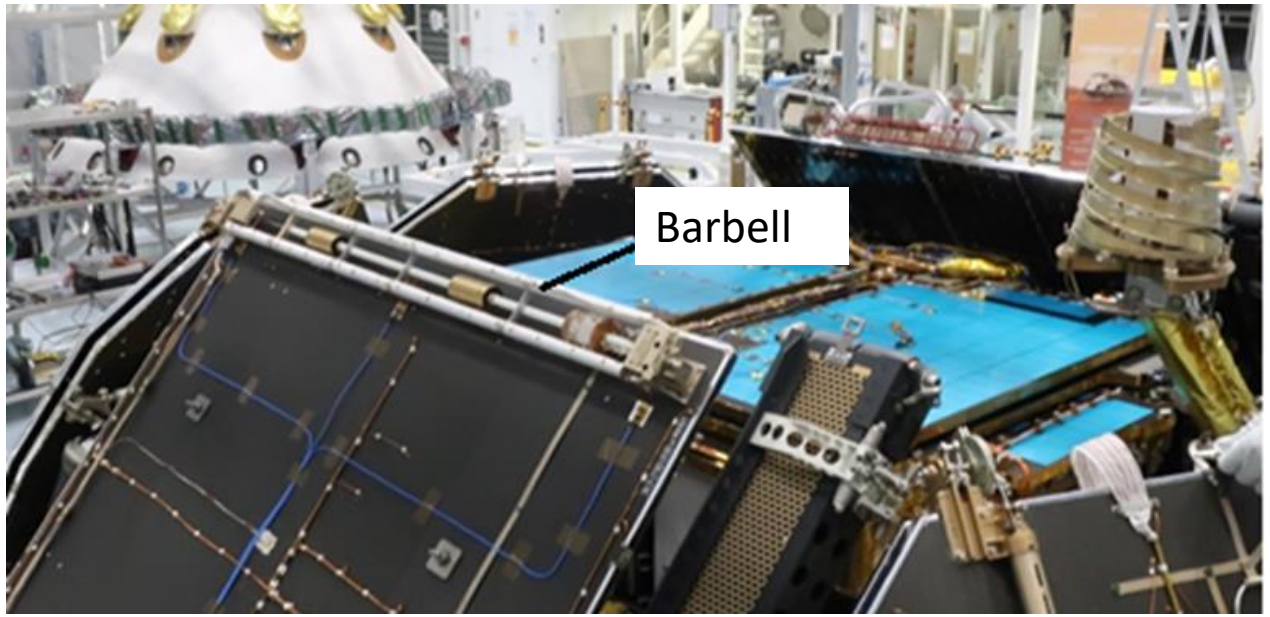
Low frequency electromagnetic sounding is advantageous for detecting deep underlying water layers that cannot be detected using radar or seismic methods (Delory et al. 2007; Grimm et al. 2009).

Electro-Magnetic Analyzer (EMA)

Registration and analysis of low-frequency electromagnetic radiation on Mars was planned by an EMA sensor (Electro-Magnetic Analyzer) in the frequency range from 0.1 to 1 MHz as part of the Dust Complex experiment on the landing platform of the ExoMars project.

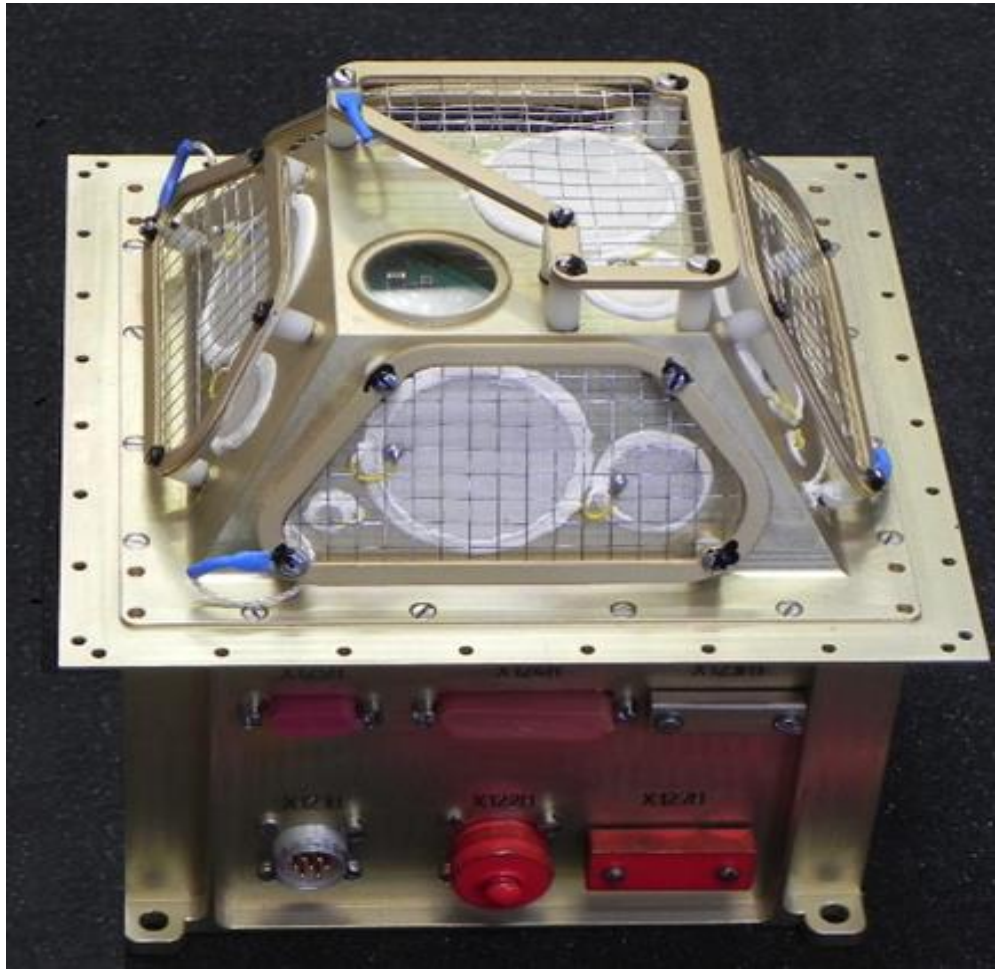
Currently, using the EMA sensor, laboratory work is being carried out simulating the physical processes of generating electromagnetic radiation occurring on Mars.





Electro-Magnetic Analyzer (EMA)

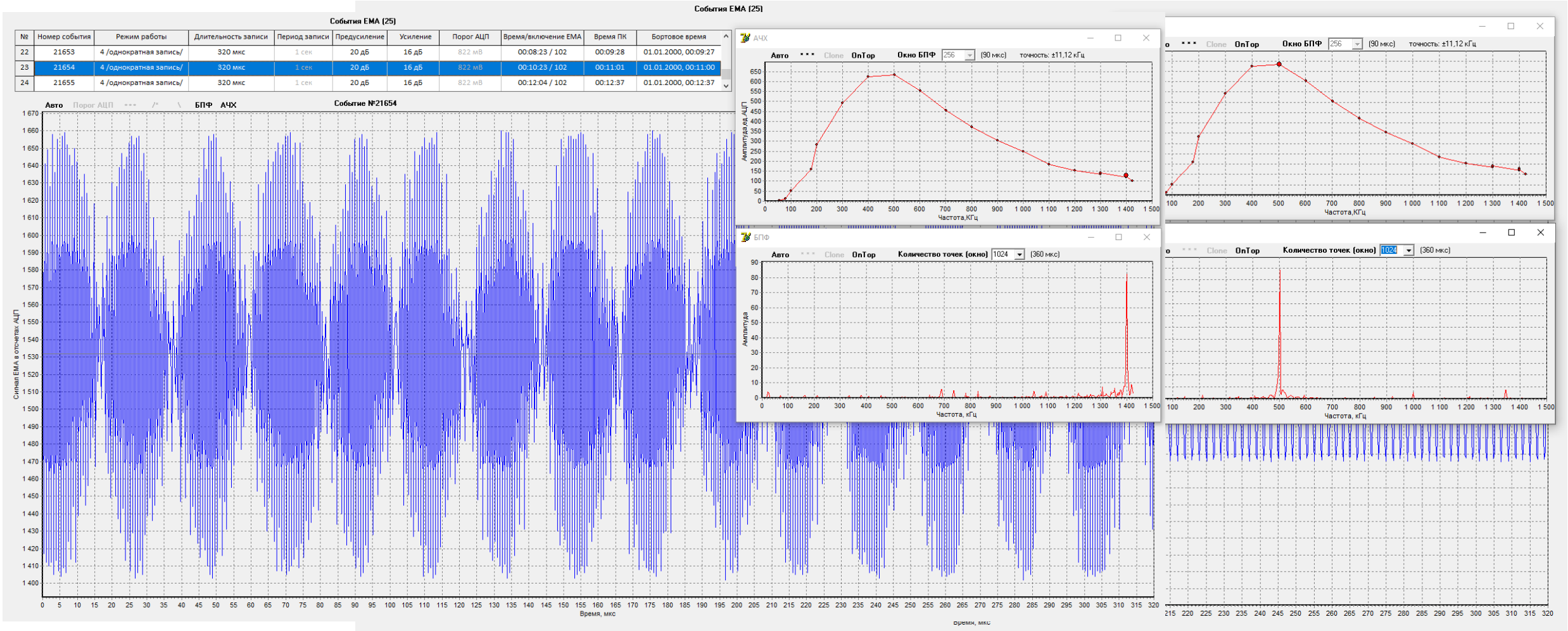
Dust Complex (DC)



The main characteristics of the EMA

	units	values
The bandwidth of the radio path at the level of 3 dB	MHz	0.12 – 1.420
The sensitivity of the signal measurements at the input of the amplifier at a S/N ratio of 6 dB.	μV	7
Field sensitivity with standard antenna	μV /m	700
Intrinsic noise at the input of the amplifier	μV	2

Device calibration



Examples of signals from an EMA sensor when exposed to an external electrostatic discharge.

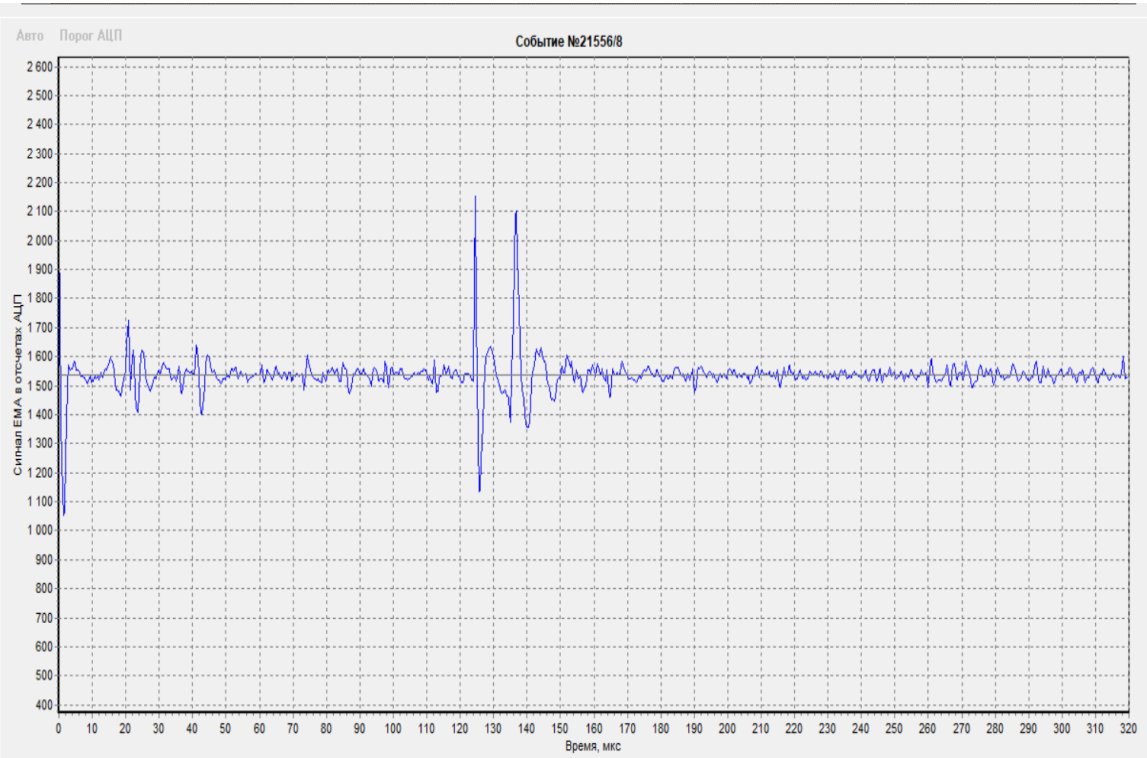


Fig. 3. A dusty Sand signal

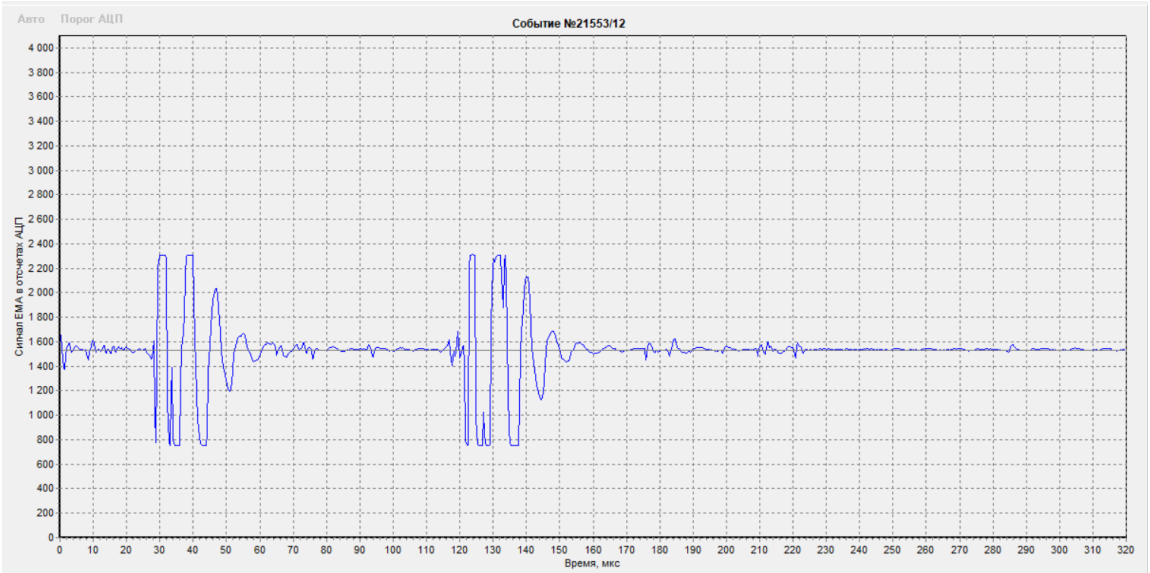


Fig. 4. A piezo ignition signal

Planned Experiments

Conclusion

The presence of EMA at the Martian surface enables worldwide exploration of Mars and provides access to the atmosphere's mysterious electrical and electromagnetic properties. Due to its effectiveness and simplicity, such an experiment should be taken into account for studying the Martian environment during prospective in situ missions.

Thank you!

Mohamad.essam@phystech.edu

https://www.linkedin.com/in/mohamad-essaam/