MobileMT - data acquisition and data processing fundamentals

from innovations to discoveries

Topics

- MobileMT definition
- Source of Primary field
  - Natural EM field transmitter
- Receivers
  - Ground electric field lines, signal and reference
  - Magnetic components in the air
- Data processing
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  - main principles
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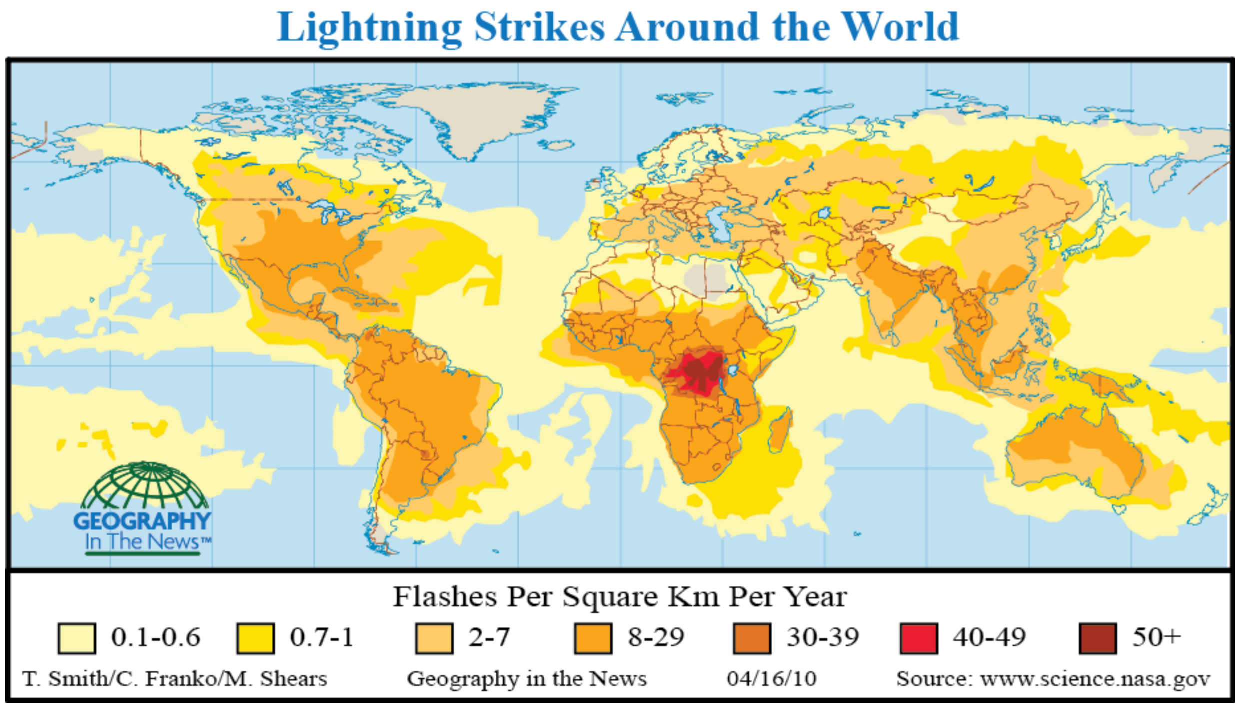
  - frequency windows for harmonic averaging
  - finals

MobileMT definition

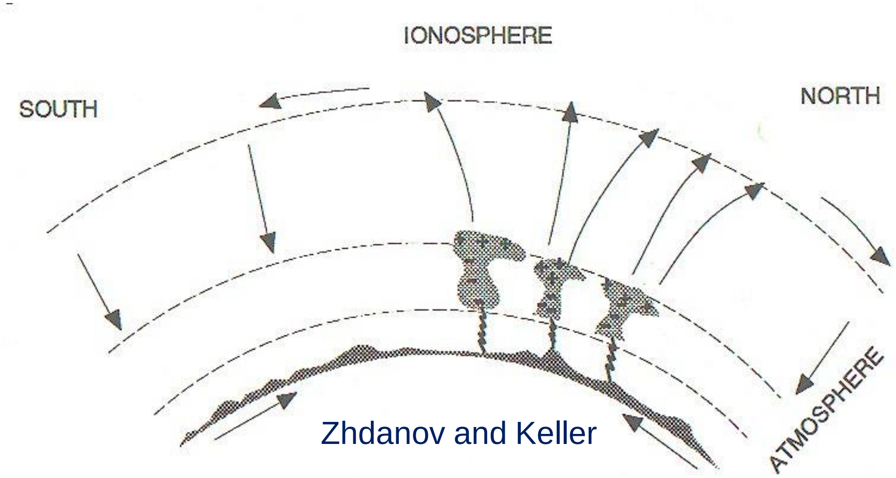
- passive measurement of the earth's natural magnetic (***H***) field variations in the air with simultaneous measurement of natural electric field (***E***) on the surface;
- Measure changes in ***H*** with time and space and changes in ***E*** with time;
- Frequency range 30 Hz to 20,000 Hz.

The combined (***E*** and ***H***) system measures combination of tensor and scalar (rotational invariant) components as the transfer function (in-phase and quadrature) of a total magnetic field, through the three orthogonal directions measurements of an airborne receiver, to the two orthogonal horizontal directions of electric field measured at a ground base location.

Natural electromagnetic field transmitter – worldwide thunderstorm activity



From: https://blog.education.nationalgeographic.org



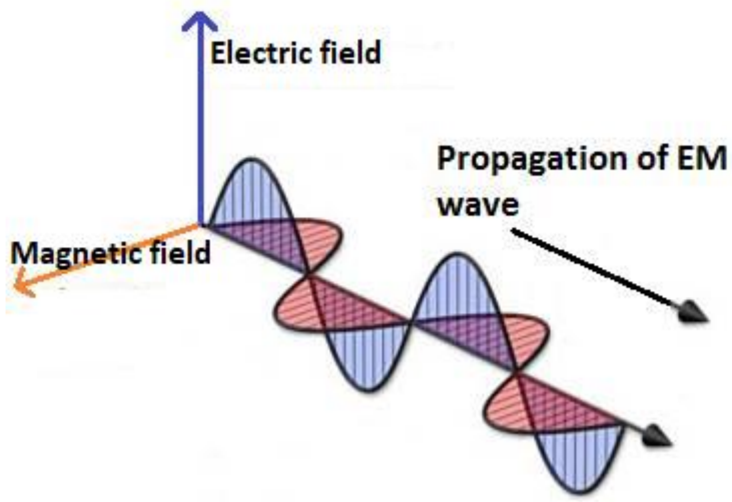
Energy travels around the Earth in waveguide bounded by Earth surface and Ionosphere;
Electromagnetic Field Frequencies > 1Hz (audio frequency range);
The source fields are variable and considered as plane waves.

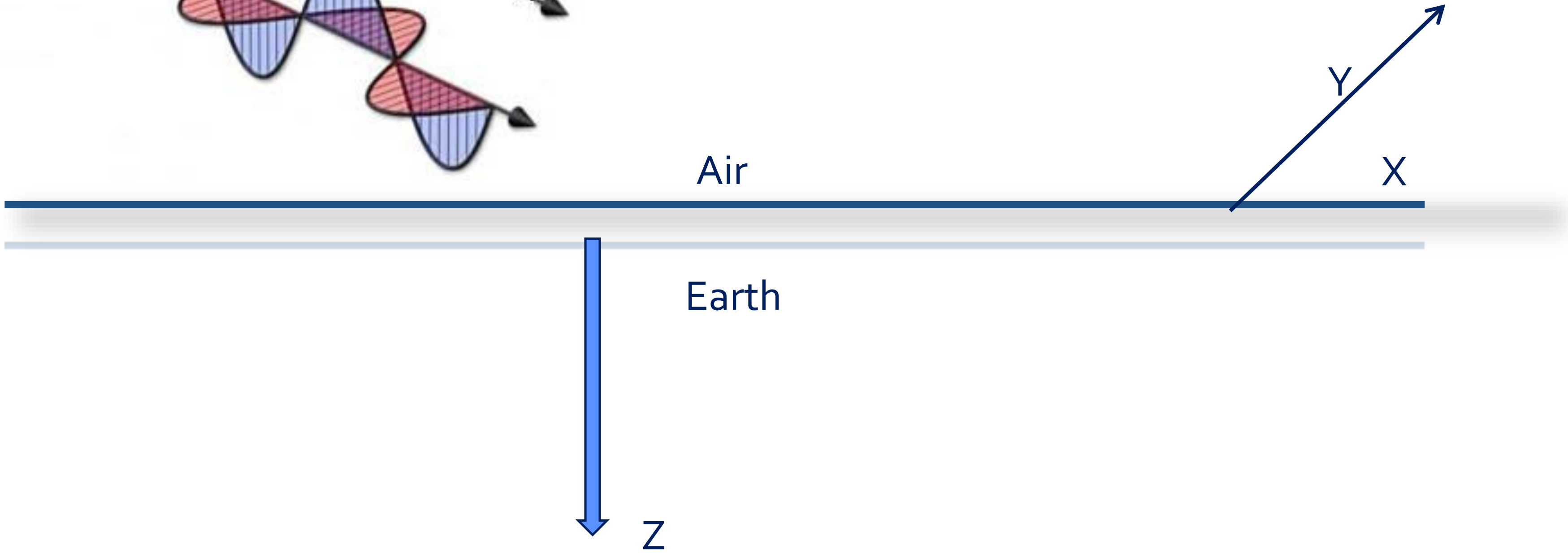
Natural electromagnetic field transmitter

Time-varying magnetic field induces an electric current in the earth

At the surface, EM waves are polarized into x,y plane,
Electric field in vertical direction Ez = 0

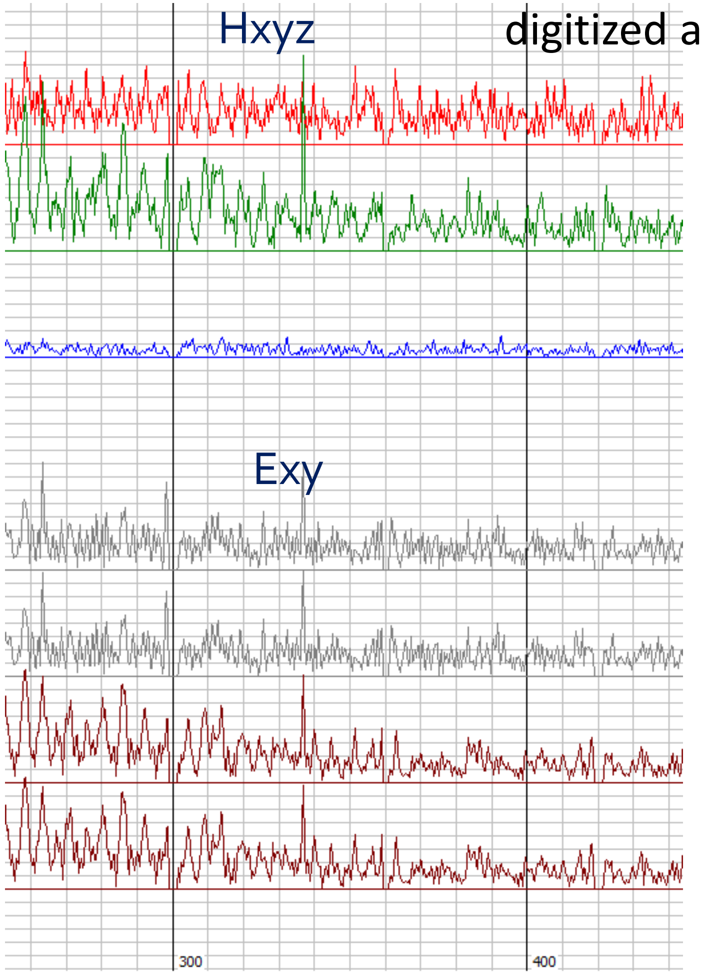
The generated electric current creates a secondary superimposed electromagnetic field



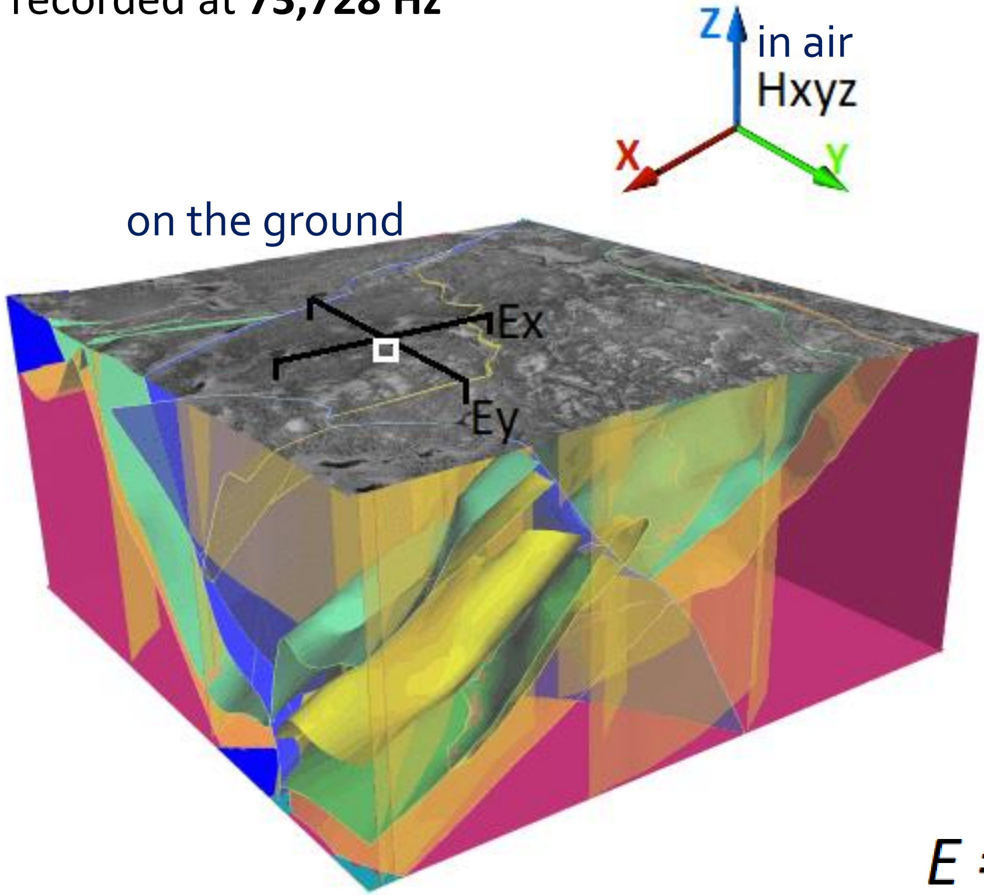


Signals Receivers

MobileMT's electromagnetic data is digitized and recorded at **73,728 Hz**

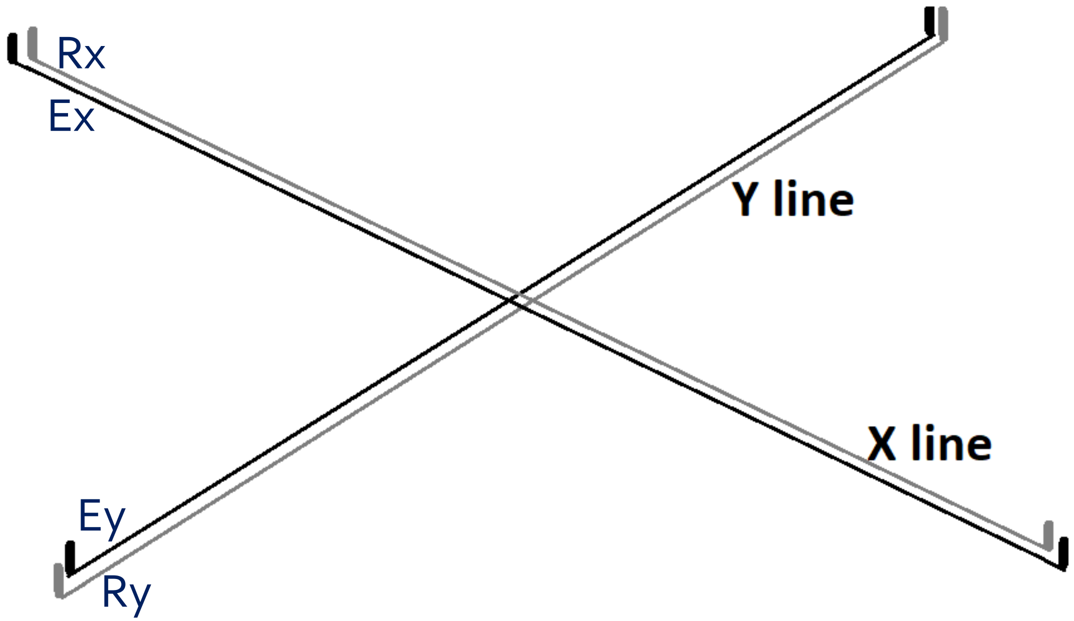


Time series data



$$E = \begin{bmatrix} Ex \\ Ey \\ 0 \end{bmatrix} \qquad H = \begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix}$$

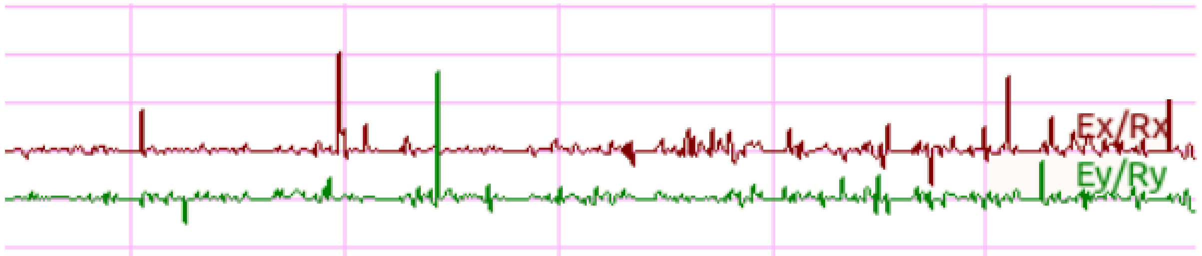
Receivers: Electric components *Ex, Ey*



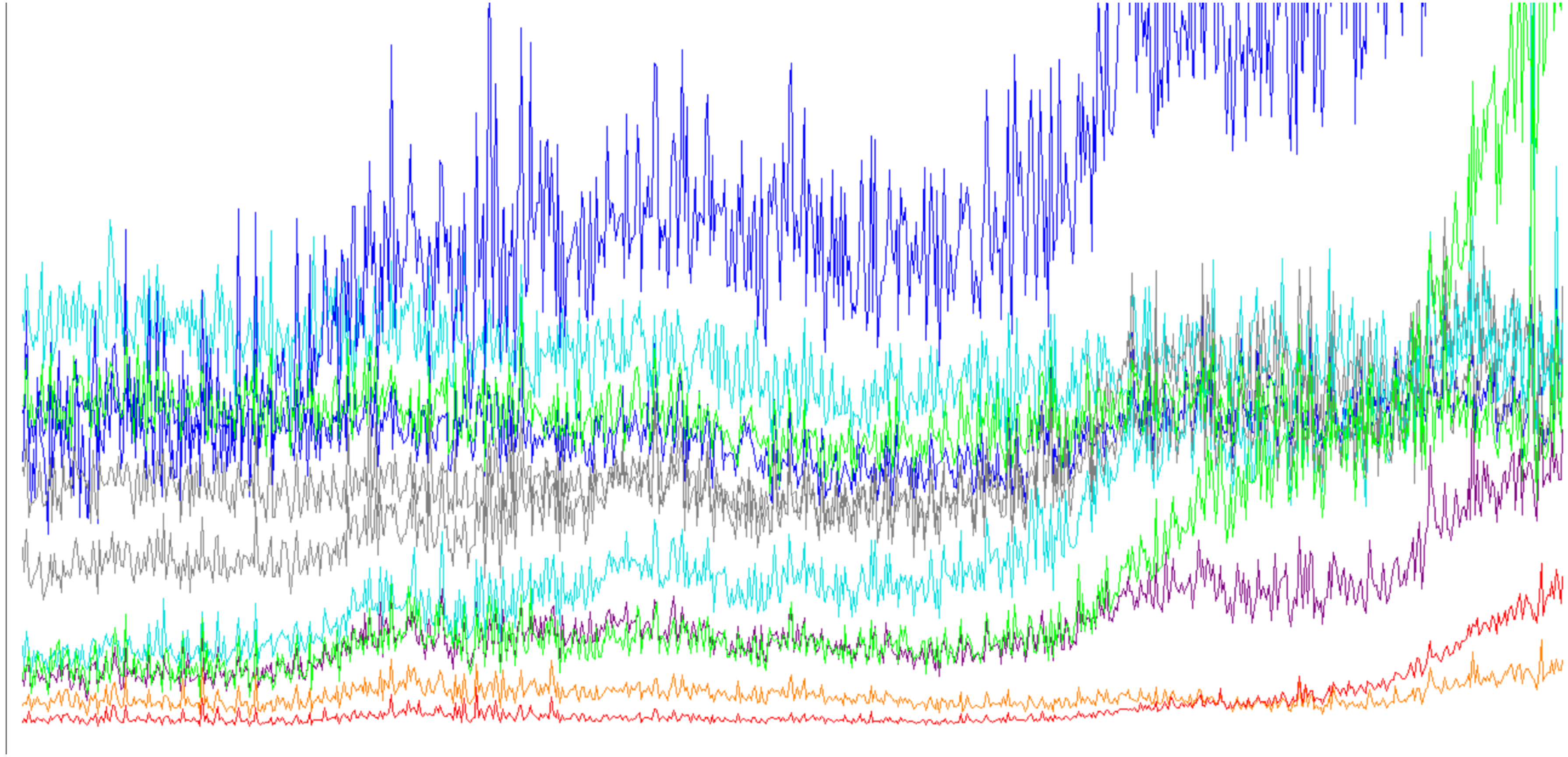
Two horizontal electrical components of MT field on the stationary base station are measured by four independent grounded electrical lines

The electric signal, reference and magnetic components in the air are synchronized by GPS timing signals.

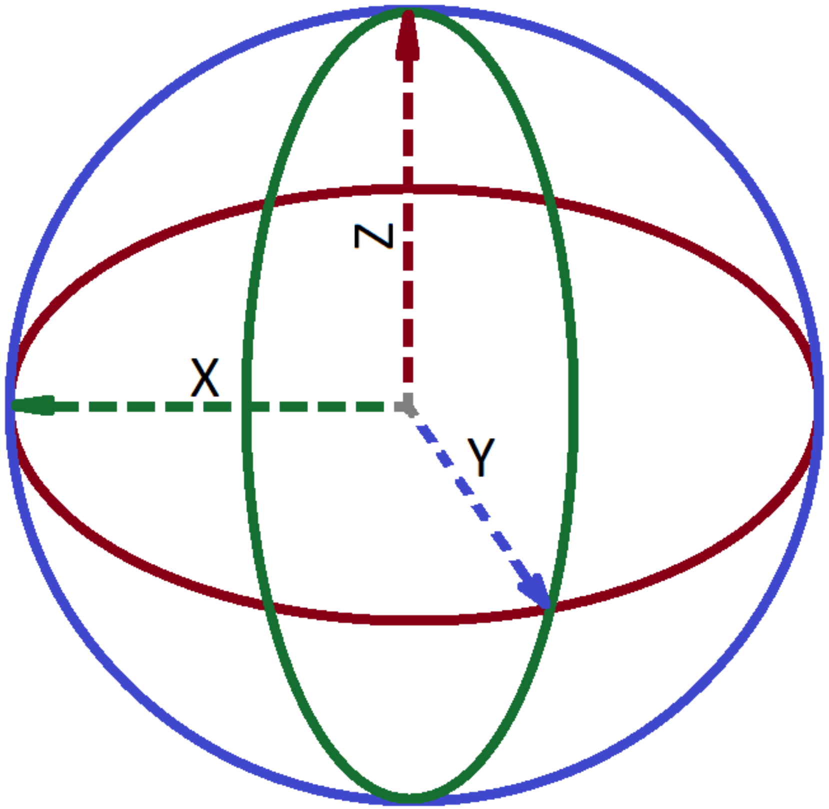
One orthogonal pair of the electrical lines is signal, another is reference to eliminate the data bias distortions:

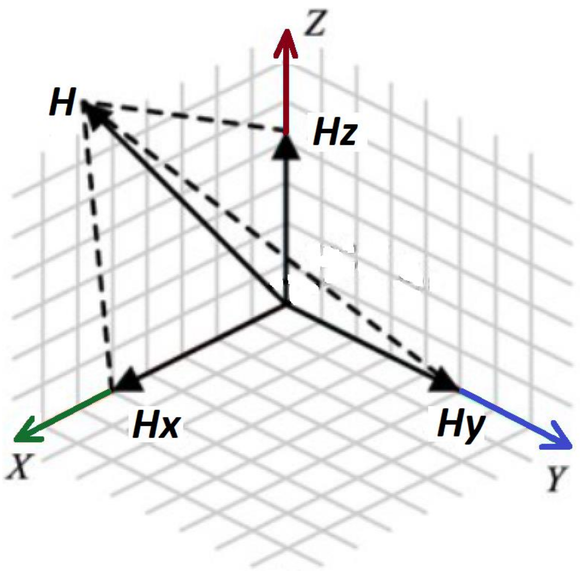


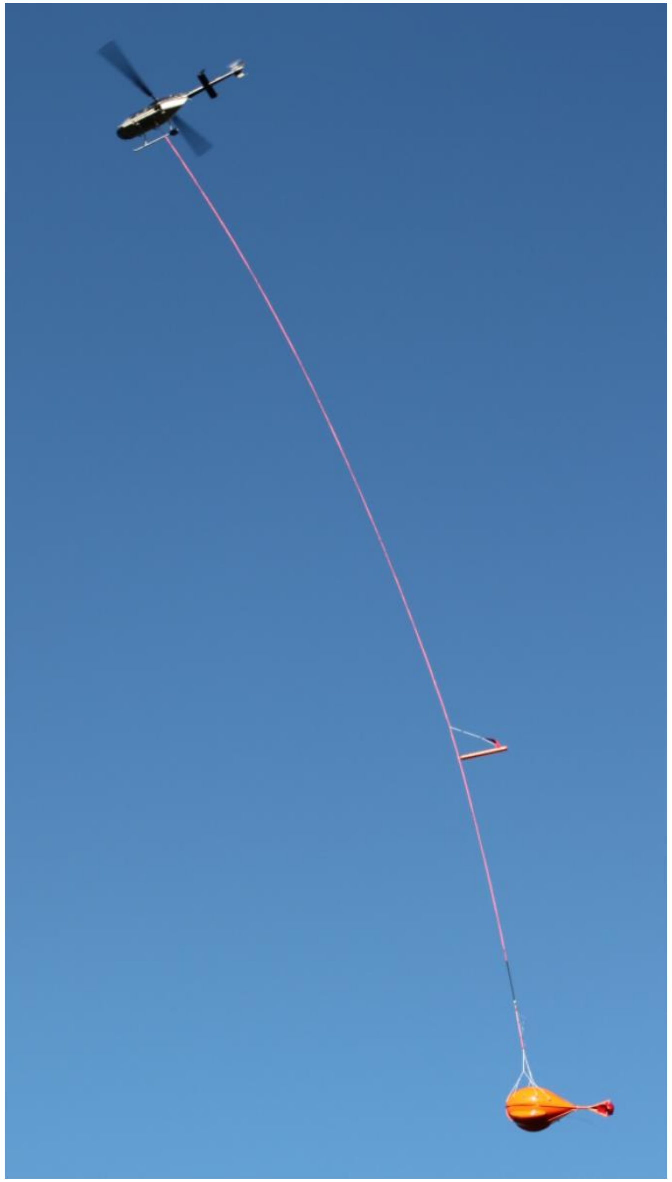
Receivers: Electric field variations during 8 hours of a day



Receivers: Magnetic components *Hx, Hy, Hz* in the air



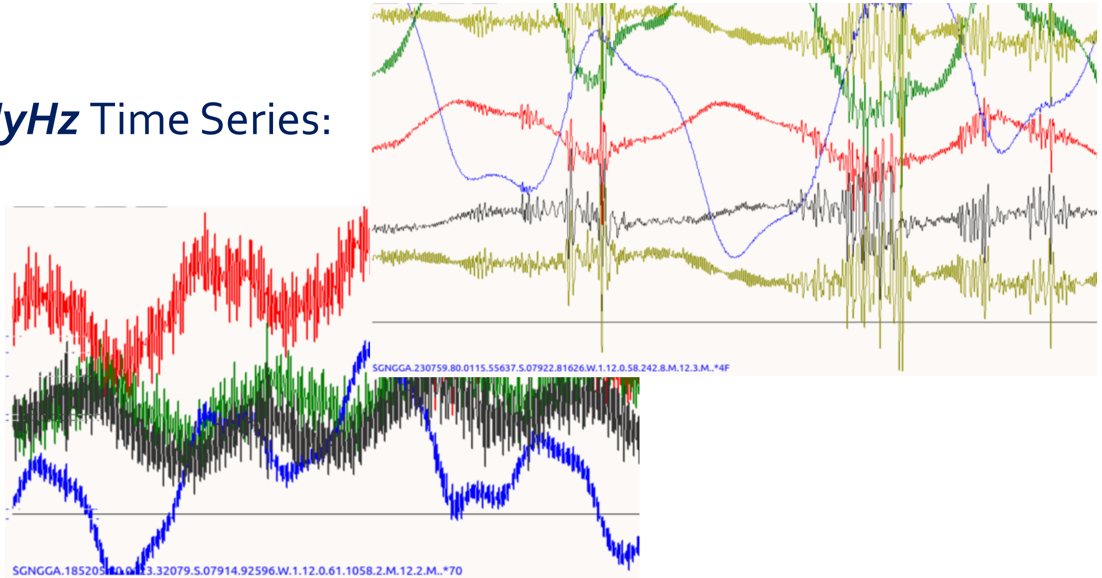




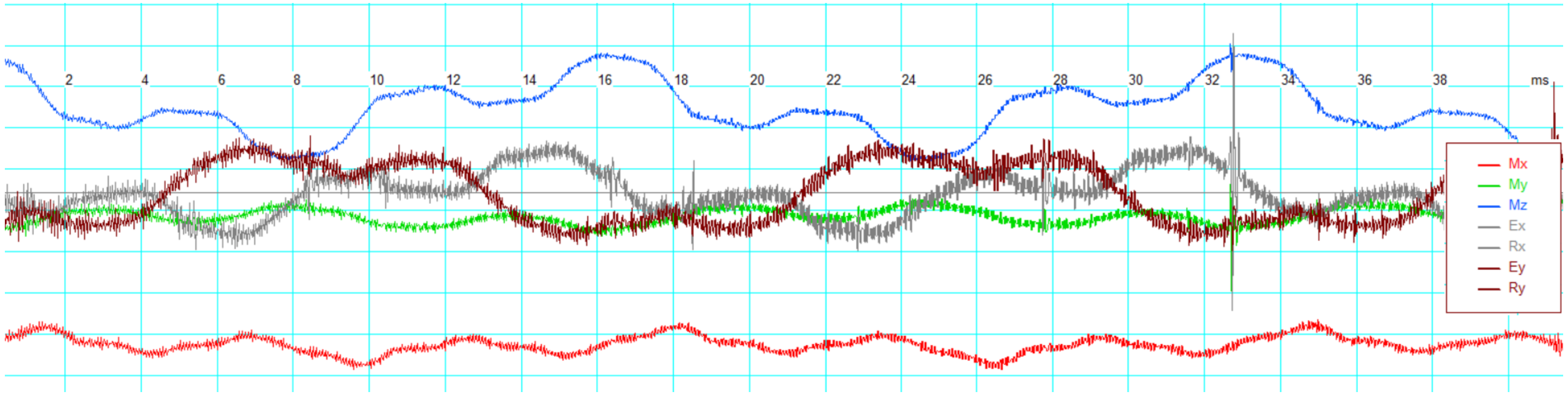
Data processing – the goal and time series

The data processing program merges the stationary measured electrical two horizontal components and the moving orientation irrelevant receiver of three magnetic field components into one file. Each file consists of 5 min data (~600 Mb).

Synchronized and jointed ***ExEyHxHyHz*** Time Series:



The data processing goal is determining the MT admittance tensor response from the time series data (or converting time-domain data to frequency domain)



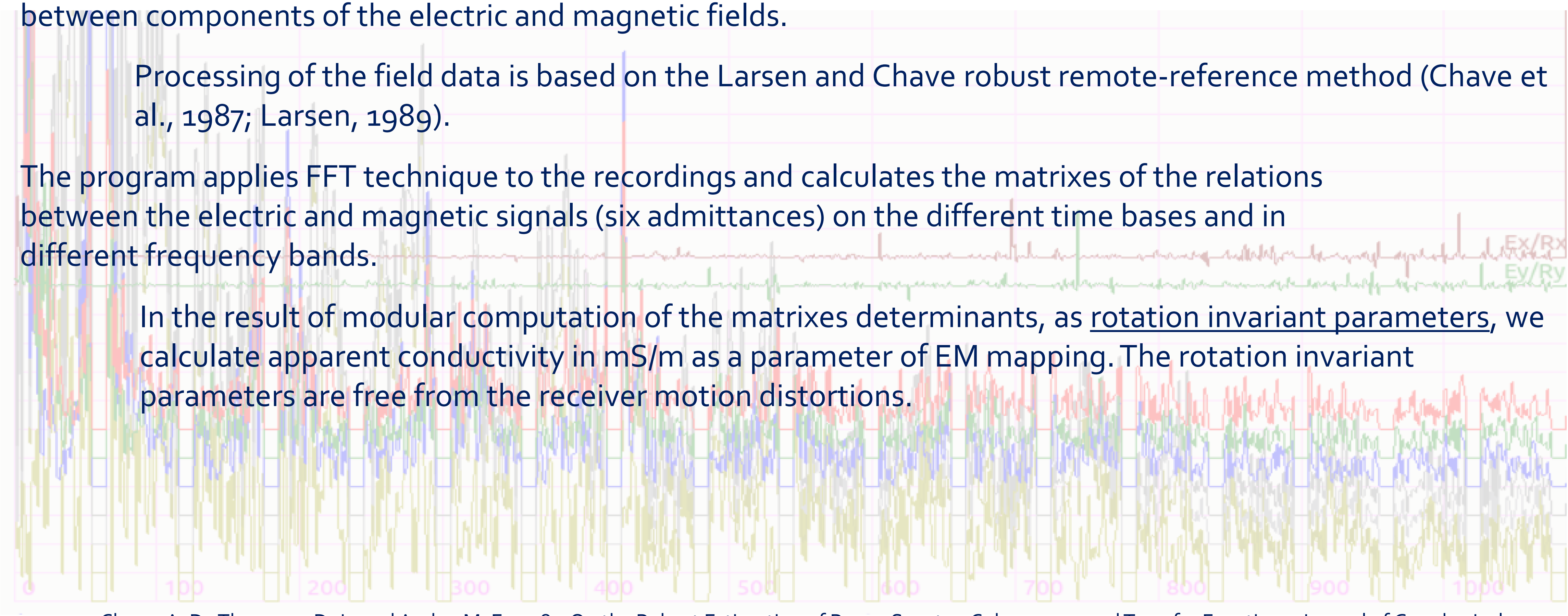
Data processing – main principles

Exploiting signals of two horizontal electric components along with three magnetic components we can process them with the magnetotellurics response functions based on linear relations between components of the electric and magnetic fields.

Processing of the field data is based on the Larsen and Chave robust remote-reference method (Chave et al., 1987; Larsen, 1989).

The program applies FFT technique to the recordings and calculates the matrixes of the relations between the electric and magnetic signals (six admittances) on the different time bases and in different frequency bands.

In the result of modular computation of the matrixes determinants, as rotation invariant parameters, we calculate apparent conductivity in mS/m as a parameter of EM mapping. The rotation invariant parameters are free from the receiver motion distortions.



Chave, A. D., Thomson, D. J., and Ander, M. E., 1987, On the Robust Estimation of Power Spectra, Coherences, and Transfer Functions: Journal of Geophysical Research, **92**, 633-648.

Larsen, J. C., 1989, Transfer functions: smooth robust estimates by least-squares and remote reference methods: Geophysical Journal International, **99**, 645-663.

Data processing – admittance tensor

The admittances (***Y***) are represented as the electric field horizontal vectors projection into the space of the magnetic field three components.

Generalizing the Weiss-Parkinson relationship (Berdichevsky and Zhdanov, 1984), such as that measured three orthogonal magnetic field components (***H***xyz) are linearly related to the horizontal electric fields measured on the ground (***E***xy, reference), with adoption it to the admittances domain (***Y***):

$$\begin{bmatrix} Hx \\ Hy \\ Hz \end{bmatrix} = \begin{bmatrix} Yxx & Yxy \\ Yyx & Yyy \\ Yzx & Yzy \end{bmatrix} \begin{bmatrix} Ex \\ Ey \end{bmatrix} \qquad (1)$$

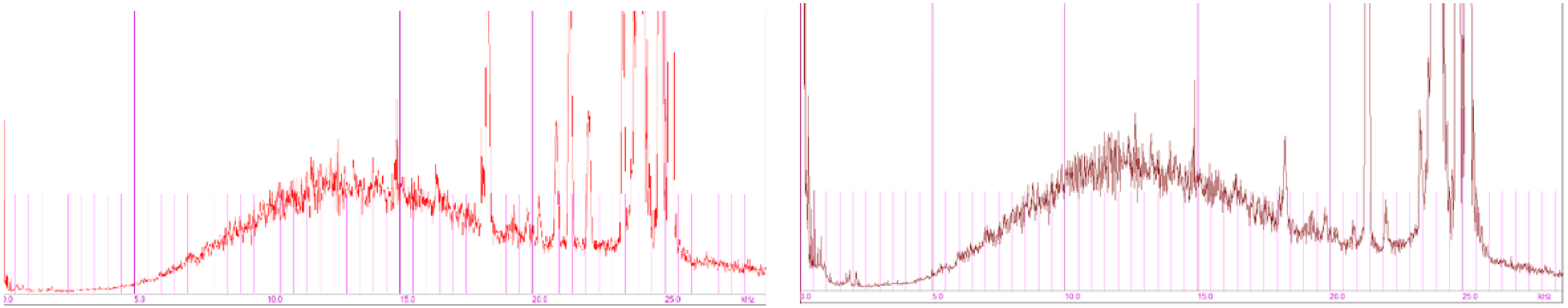
The complex data spectrums (field examples in Figures on the next slide) is expressed in apparent conductivity (**σ**), as **final output MobileMT data for each frequency** :

$$\boldsymbol{\sigma} = \mu\omega|Y^2| \qquad (2)$$

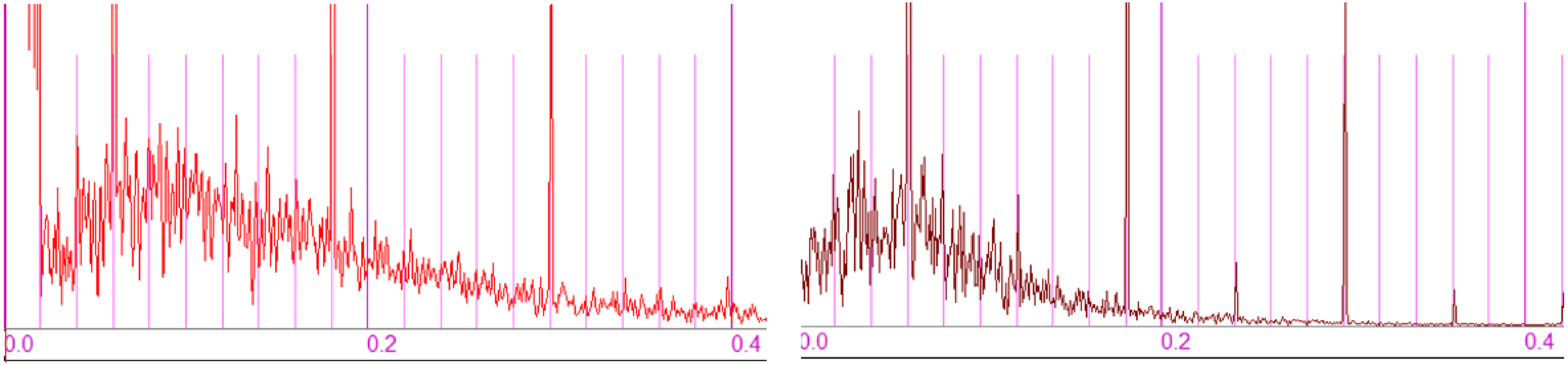
where ***Y*** is the determinant of the corresponded matrix in (1); $Y^2 = \mathrm{im}(Y^2)/\mathrm{re}(Y^2)$; **μ** is the magnetic permeability of free air and **ω** is the angular frequency.

Berdichevsky, M.N., and M.S. Zhdanov, 1984, Advanced theory of deep geomagnetic sounding: Elseiver.

Data processing – examples of data spectrums



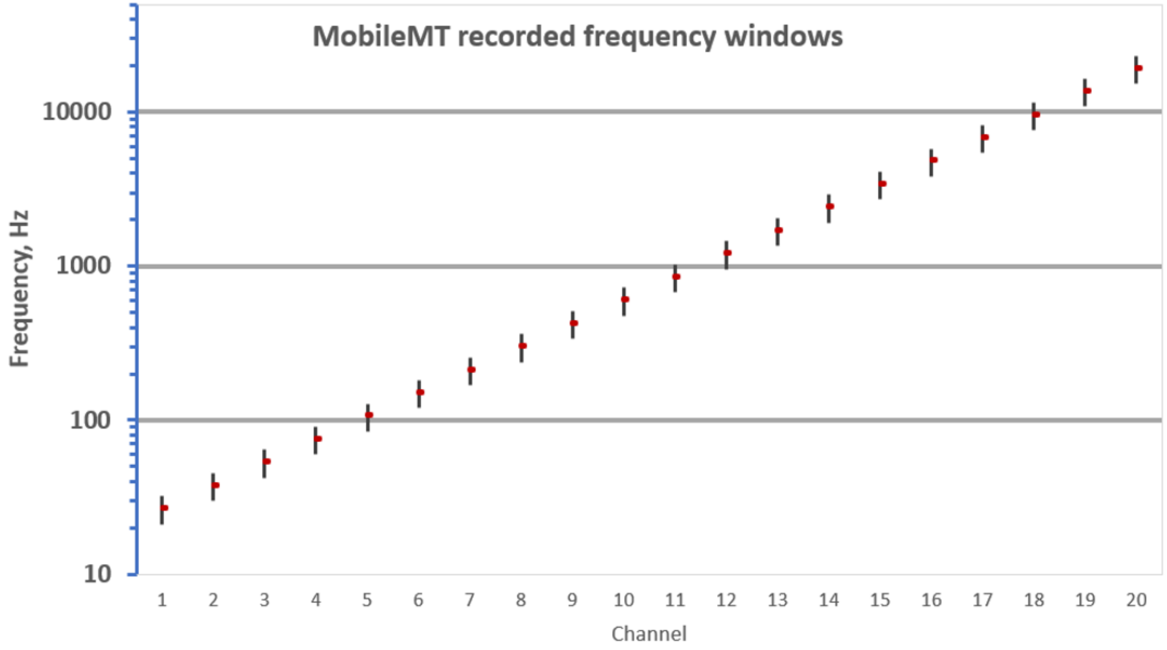
Airborne magnetic X-coil spectrum up to 30,000 Hz range (left) with the corresponding electric X-line 1 spectrum (right)



Airborne magnetic X-coil spectrum up to 400 Hz range (left) with the corresponding electric X-line 1 spectrum (right)

Data processing – MobileMT frequency windows

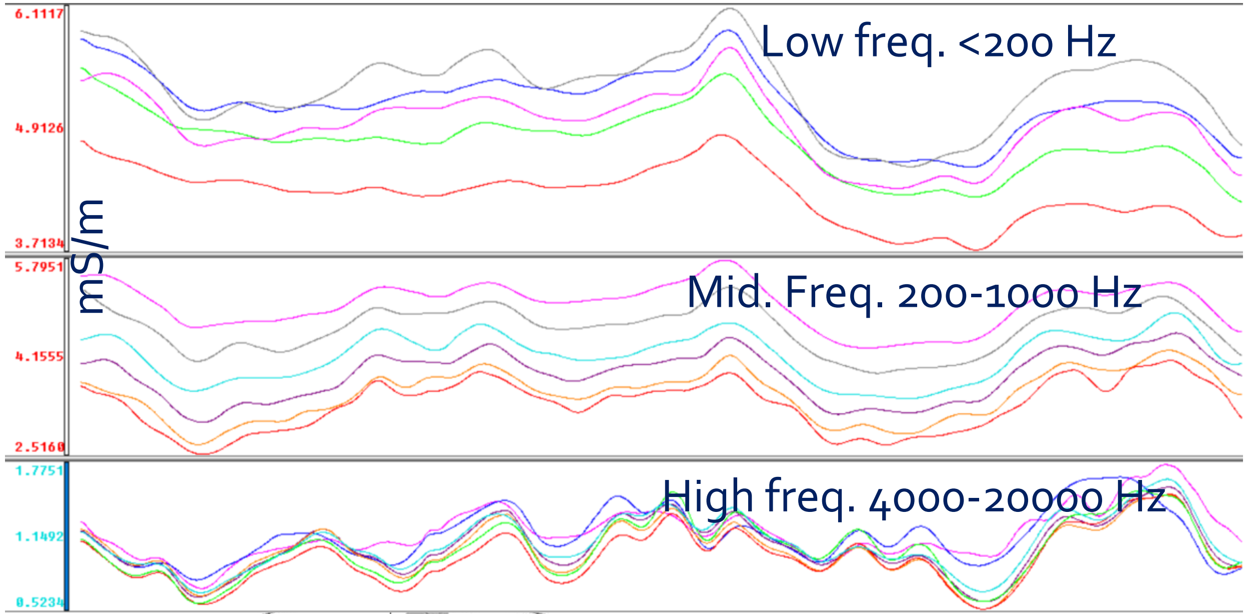
Solutions of the equations (1) are obtained by averaging over a number of closely spaced frequencies
An example of frequency windows used for harmonics averaging:

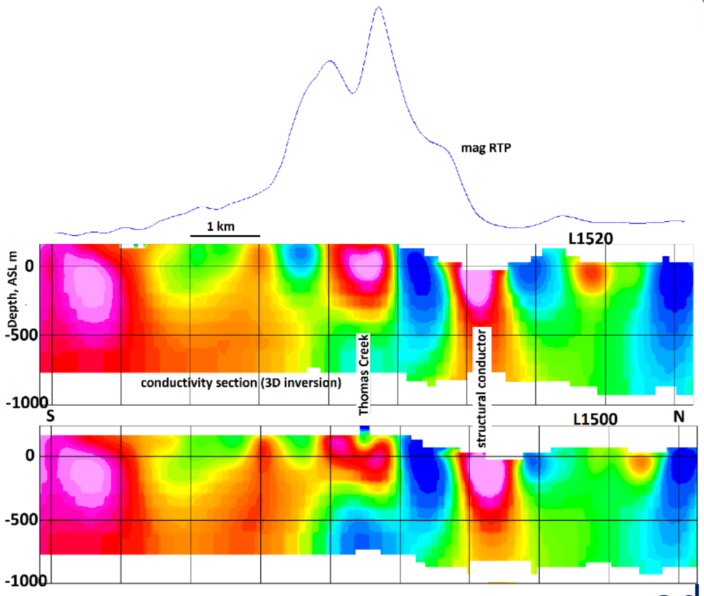


Frequency windows width and the windows number in the range are customizable depending on signal strength and frequency of any source of industrial noise.

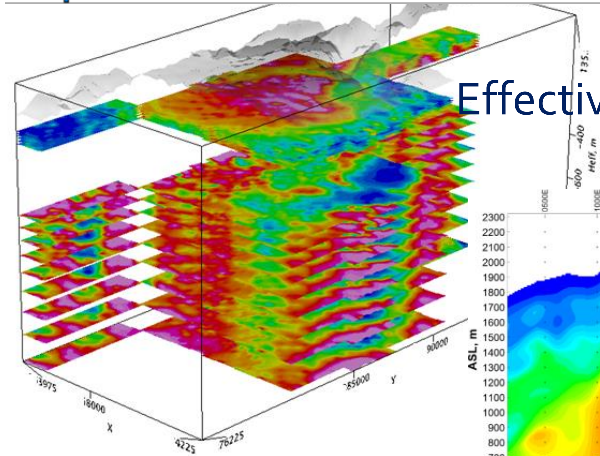
Data processing – finals

MobileMT output data examples

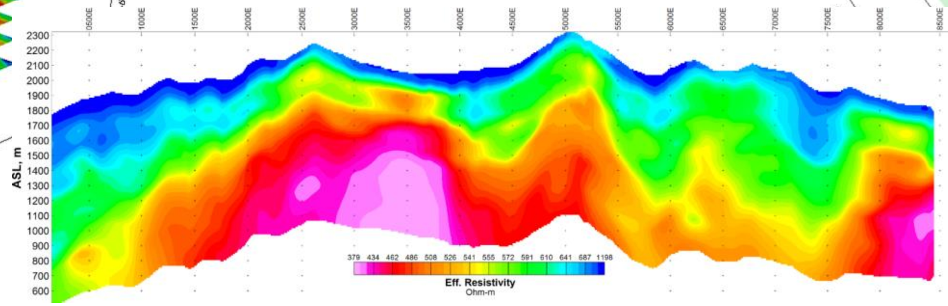


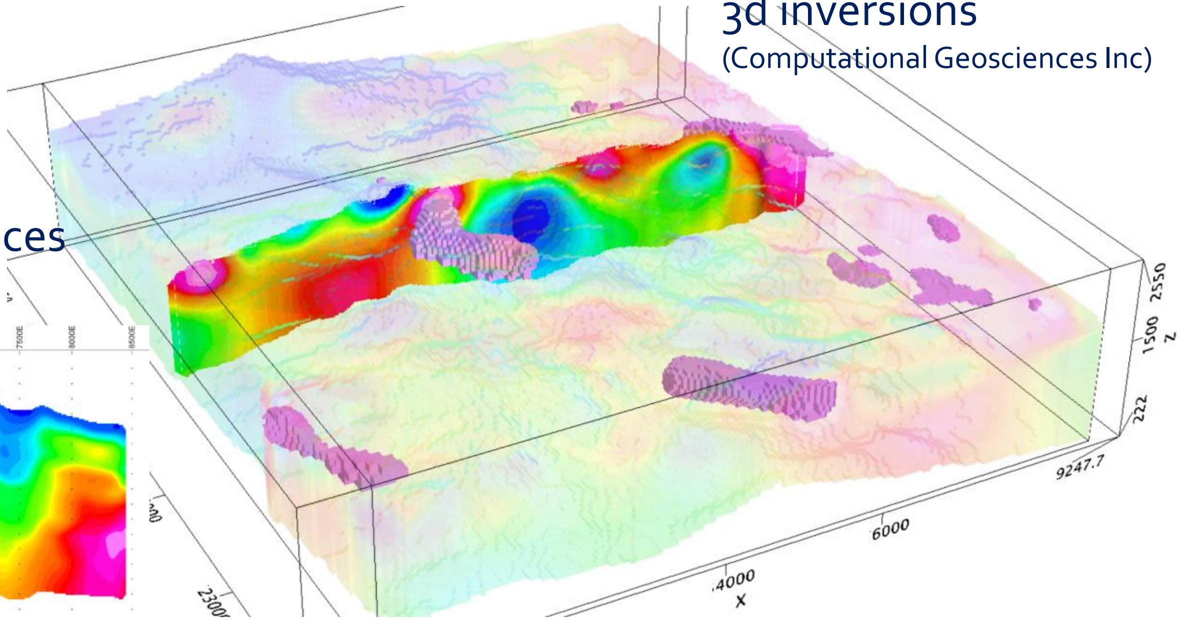


3d inversions
(Computational Geosciences Inc)



Effective resistivity sections and depth slices





Thank you!

"Improved three-component receiver systems will most likely be developed, which if oriented would provide vector data, or if not would provide a total-field measurement…"

Jansen, J.C., Cristall, J.A. (2017). Mineral Exploration Using Natural EM Fields. Exploration'17