A Controlled-Source Radio-Magnetotelluric Experiment in Aleksandrovka, Russia

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Introduction

Radio-Magnetotelluric (RMT) method is based on measurements of the electromagnetic (EM) field of remote radio transmitters in a frequency range of 10 – 1000 kHz where CSRMT measures the EM field from a controlled-source in a wider frequency range of 1 – 1000 kHz. This, results to a higher signal to noise ratio compare to RMT method. Two perpendicular transmitters with 800 meters long, are used in this experiment. Therefore, the full impedance tensor and the tipper elements will be observed. In order to increase the data coverage, RMT measurements also carried out when the transmitter was off . These, also used to test the near-field condition.
In this study, near-field is also been considered as well as far-field.

Instruments and Field Survey

Figure 1 (a), shows the RMT receiver device with capability of recording two electric and three magnetic components of EM field. Figure 1 (b) and (c) indicate the magnetic coils and the transmitter device, respectively.

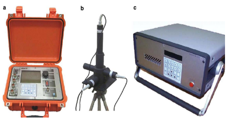

Fig. 1: RMT/CSRMT survey instruments

	D1	D2	D3	D4
Frequency range(kHz)	1-10	10-100	100-300	100-1000
Sampling frequency(kHz)	39	312	832	2496

Fig. 2: Frequency range and sampling frequency

The survey accomplished in Aleksandrovka village in the Kaluga region in Russia, where there are sedimentary rocks from a paleo-valley with a high resistivity lens of roughly 15 meter thickness at about 15 meter depth.
As is shown in figure 3, far-field data has been acquired from eight profiles (blue points), with 20 meter separation between the stations and 400 to 600 distance from the transmitters (red lines). In each station, at least seven measurements have been recorded. Three frequency bands of D1, D2 and D4 corresponding to each transmitter and one RMT record while the transmitters were off.
Figure 2, shows the measurement specifications.

Fig. 3: Survey area and the location of transmitters and profiles

Data Processing

Time series processing is the first step to estimate the transfer functions. Here is a summarized steps for RMT and CSRMT data processing and a brief explanation:
- Dividing the record segments into equal lengths.
- Multiplying each segment with a window function. The common window functions are “rectangular” and “Blackman”.
- Applying Fourier transform to each segment with calibration.
- Calculating the auto and cross spectra.
- Estimation of the transfer functions and their errors.

Here is a sample indicating how time series look like.

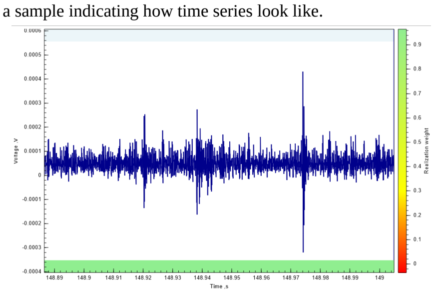

Fig. 4: A time series sample

CSRMT/RMT Frequency Spectra

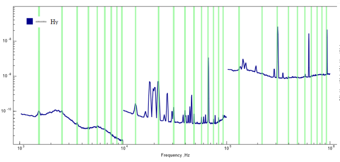

Fig. 5: CSRMT Spectra of Hy for three frequency bands

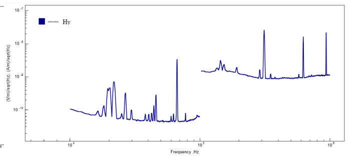

Fig. 6: RMT Spectra of Hy for two frequency bands

Frequencies of 512 Hz, 4.4 and 44 kHz were used in both transmitters as the D1, D2 and D3 main frequencies respectively. After applying Fourier transform to the time series and calculating the frequency spectra, only main frequencies and their harmonics were considered during processing. So that, we can make sure that the spikes appearing in the spectra, are related to transmitters and other sources have not produced them.
Figure 5 and 6, demonstrate the spectra of Hy component related to CSRMT and RMT data from station 1 of profile 8 respectively. The green lines, indicate the main frequencies and their harmonics in each frequency band corresponding to transmitter source.

Transfer Functions

As is in the MT method, the E and H fields are related through impedance tensor which can be transformed into apparent resistivity and impedance phase. The scalar resistivities and phases are simply obtained by appropriate auto and cross spectra of EM field. The vertical and the horizontal magnetic field components are related through tipper vector.

$$\begin{bmatrix}E_x\\E_x\end{bmatrix}=\begin{bmatrix}Z_{xx}&Z_{xy}\\Z_{yx}&Z_{yy}\end{bmatrix}\begin{bmatrix}H_x\\H_y\end{bmatrix}\quad,\qquad [H_z]=[A\quad B]\begin{bmatrix}H_x\\H_y\end{bmatrix}$$

$$\rho_{a_{xy}}=\frac{1}{\omega\mu_0}.\left|Z_{xy}\right|^2,\qquad \varphi_{xy}=\arctan\left(\frac{ImZ_{xy}}{ReZ_{xy}}\right)$$

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In the figures below, the transfer functions related to the station 3 from profile 8 is shown.

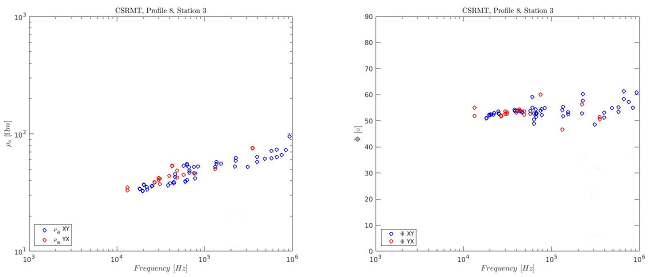

Fig. 7: Apparent resistivity and phase plots against frequency for station 3

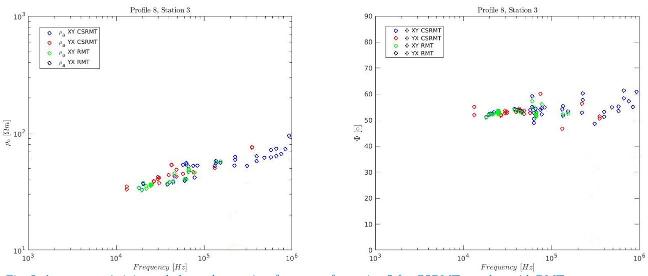

Fig. 8: Apparent resistivity and phase plots against frequency for station 3 for CSRMT together with RMT

Considering the RMT and CSRMT data in the figure 8, a good coincidence is observed in the frequency range of 10 to 100 kHz.

Conclusions and Outlook

- Reasonable RMT and CSRMT data measurements were done successfully.
- Data were acquired for both near and far field zones.
- Different data processing methods will be applied to the data in order to compare and achieve more reliable results.
- 2D/3D modelling and inversion will be applied in the future.