GFZ

Helmholtz-Zentrum
POTSDAM

Helmholtz-Zentrum Potsdam
Deutsches
GeoForschungsZentrum

Oliver Ritter, Gerard Muñoz, Ute Weckmann,
Reinhard Klose, Paula Rulff, Stefan Rettig,
Carsten Müller-Brettschneider, Manfred Schüler,
Gregor Willkommen, Diane Eydam

A Permanent Magnetotelluric Reference Station in Wittstock, Germany (Report)

Scientific Technical Report STR15/09 - Data
GIPP Experiment- and Data Archive

HELMHOLTZ
GEMEINSCHAFT

Recommended citation:

Ritter, O., Muñoz, G., Weckmann, U., Klose, R., Rulff, P., Rettig, S., Müller-Brettschneider, C., Schüler, M., Willkommen, G., Eydam, D. (2015) A Permanent Magnetotelluric Reference Station in Wittstock, Germany. *Scientific Technical Report 15/09 - Data, GFZ German Research Centre for Geosciences.*
DOI: http://doi.org/10.2312/GFZ.b103-15092

Supplementary Datasets:

Ritter, O., Weckmann, U., Muñoz, G., Klose, R., Rettig, S., Schüler, M., Müller-Brettschneider, C., Willkommen, G., Rulff, P. (2015) Magnetotelluric Reference Station Wittstock. *GFZ Data Services.*
DOI: http://doi.org/10.5880/GFZ.2.2.2015.001

Imprint

Helmholtz Centre Potsdam
GFZ German Research Centre
for Geosciences

Telegrafenberg
D-14473 Potsdam

Published in Potsdam, Germany
September 2015

ISSN 2190-7110

DOI: http://doi.org/10.2312/GFZ.b103-15092
URN: urn:nbn:de:kobv:b103-15092

This work is published in the GFZ series
Scientific Technical Report (STR)
and electronically available at GFZ website
www.gfz-potsdam.de

Oliver Ritter, Gerard Muñoz, Ute Weckmann,
Reinhard Klose, Paula Rulff, Stefan Rettig,
Carsten Müller-Brettschneider, Manfred Schüler,
Gregor Willkommen, Diane Eydam

A Permanent Magnetotelluric Reference Station in Wittstock, Germany (Report)

Scientific Technical Report STR15/09 - Data
GIPP Experiment- and Data Archive

A Permanent Magnetotelluric Reference Station in Wittstock, Germany (Report)

O. Ritter, G. Muñoz, U. Weckmann, R. Klose, P. Rulff, S. Rettig, C. Müller-Brettschneider, M. Schüler, G. Willkommen, D. Eydam.

GFZ Potsdam

Summary

The sources for the magnetotelluric method are naturally occurring electromagnetic field variations. Electromagnetic currents are excited over a wide frequency range in the Earth's ionosphere by solar activity and global lighting discharges. While these sources are available everywhere on Earth and at all times, their signal strength varies considerably.

The so-called remote-reference technique is an effective way to improve magnetotelluric data quality by referencing the electromagnetic fields recorded at a local site to simultaneously recorded, undisturbed fields at a remote site. The remote-reference approach has become standard for magnetotelluric field work, particularly in areas with high levels of man-made electromagnetic noise; i.e. almost everywhere in central Europe. Identifying a suitable location for a clean remote site is difficult and time-consuming. Maintaining such a site in addition to normal field operations is expensive and logistically challenging.

A permanently installed reference station simplifies MT measurements considerably. The radius for which source fields are coherent depends mostly on the frequency content of the signals and the latitude of observations. According to our own tests, signals are coherent at frequencies of up to 10 kHz over distances of 1000 km.

After a reconnaissance operation during which several locations all over Germany were tested, we identified an urban forest near the town of Wittstock in northern Germany as a suitable location for a reference station. A preliminary installation of the reference station was accomplished by mid-2010. The permanent installation in a wooden hut and operating with a range of sensors and sampling rates is available since November 2010. Meanwhile the data of the Wittstock site have been used very successfully to re-process a number of magnetotelluric stations in Germany.

This report describes the installation, the type of sensors and the recorded data sets, which are freely available on request. The datasets are published and accessible via http://doi.org/10.5880/GFZ.2.2.2015.001. The dataset description was published as Scientific Technical Report – Data and is available via http://doi.org/10.2312/GFZ.b103-15092.

Table of Contents

1 Introduction

The magnetotelluric (MT) method is a geophysical deep sounding method used to determine the electrical resistivity structure of the subsurface. The sounding depth depends on the electrical resistivity of the underlying formations and on the frequency contents of the electromagnetic (EM) fields (skin effect). The EM source fields are generated in the earth's ionosphere and reach earth's surface as (quasi) plane-wave fields, which induce horizontal current systems into the electrically conductive earth (see for example Chave and Jones, 2012 and references therein).

Inhomogeneous EM fields of nearby man-made current sources interfere with the natural MT-signals and lead to disturbed data sets. Typically, such noise is coherent between electric and magnetic field components and also spatially over considerably large distances. The influence of coherent EM noise is difficult to tackle with EM data processing methods which rely mostly on statistical approaches. EM noise can lead to biased data points or severely disturbed frequency bands which can make an interpretation of the data difficult or impossible. The coherence lengths of noise sources is small however, when compared to those of the MT signals. With the remote-reference technique, local magnetic field variations are combined with simultaneously recorded magnetic field variations at a distant reference site (Gamble et al., 1979; Egbert, 1997; Ritter et al., 1998).

2 Site Location and Installation

A remote-reference site should be located far away from cultural noise sources, such as settlements, gas and power lines, electric fences etc. We tested 25 locations across Germany before deciding on a location in an urban forest near Wittstock, approximately 10 km north of the town centre (see Fig. 1 and Eydam & Muñoz, 2011). The coordinates of the station are: 53.239006° latitude (northern Hemisphere) and 12.547760° longitude (east of Greenwich).

Data were acquired using a standard broad-band MT setup (frequency range approximately 1 kHz to 1 mHz). The instruments were supplied by the Geophysical Instrument Pool Potsdam (GIPP-MT) and included GIPP-MT non-polarizing silver-silver-chloride electrodes, Metronix MFS06 induction coil magnetometers and GIPP-MT Short-Period-Automatic-Magnetotelluric real-time data recorders (S.P.A.M. Mk IV). More details can be found at: http://www.gfz-potsdam.de/en/section/geophysical-deep-sounding/servicesinfrastructure/geophysical-instrument-pool-potsdam-gipp/instruments/gipp-mt/

For the first couple of months the site was operated like a normal MT field station. MT data recording continued from May to November 2010 to assess the acquired data quality over time. By the end of 2010 a more permanent installation was completed: all cables, sensors and sensor-boxes were buried and deployed in tubes (see Fig. 2 and Fig. 3). A wooden hut was constructed to house the data loggers (Fig. 4). The required energy is provided by a 5 m^2 wide solar panel fitted to the roof of the hut charging two 200 Ah batteries. In winter, additional power is generated by a methanol fuel cell.

Fig. 1 Location of the permanent remote-reference station near Wittstock, Germany. Map: modified after Topo50 Karte der Landesvermessung und Geobasisinformation Brandenburg.

Fig. 2 Clearance in the urban forest of Wittstock with the permanent reference station.

Fig. 3 Left: installation of underground cables within PVC tubes. Shown is the central location where cables from all sensors are connected to the sensor boxes. Right: Same but now with lid open and showing cables and one sensor box.

During winter 2010/2011 data recording continued with the initial broad band setup. In spring 2011 the station was additionally equipped with Metronix MFS07 induction coils and a Geomagnet fluxgate magnetometer to extend the frequency range. All of the data are recorded with two GPS-synchronized SPAM Mk IV real-time systems.

Fig. 4: Inside the wooden hut - data are recorded with GPS-synchronized S.P.A.M. Mk IV data loggers.

In addition to the magnetic fields which are required for remote-reference processing, we continue to record electric fields. This allows application of standard MT data processing procedures and thereby a much better assessment of the overall data quality and noise levels. The non-polarizing Ag/AgCl electrodes were installed in PVC tubes filled with bentonite. Contact resistances are in the range of a few hundred Ohm. The ground contacts and stability of the electrodes are checked regularly. At the time of writing this report (July 2015) the electrodes were never changed.

Fig. 5 shows representative apparent resistivity and phase curves for the xy- and yx- components of the impedance tensor (the x-direction points to magnetic north). The data are generally of high quality and the shape of the curves indicates a predominantly 1D character of the site.

In 2011 a solar park was built approximately 6 km south of the reference site. Fig. 6 shows a comparison of frequency spectra before and after commissioning the solar power plant. A distinct and stronger 50 Hz signal is clearly visible, but the overall signal levels are similar and after processing the data quality appeared to be unaffected.

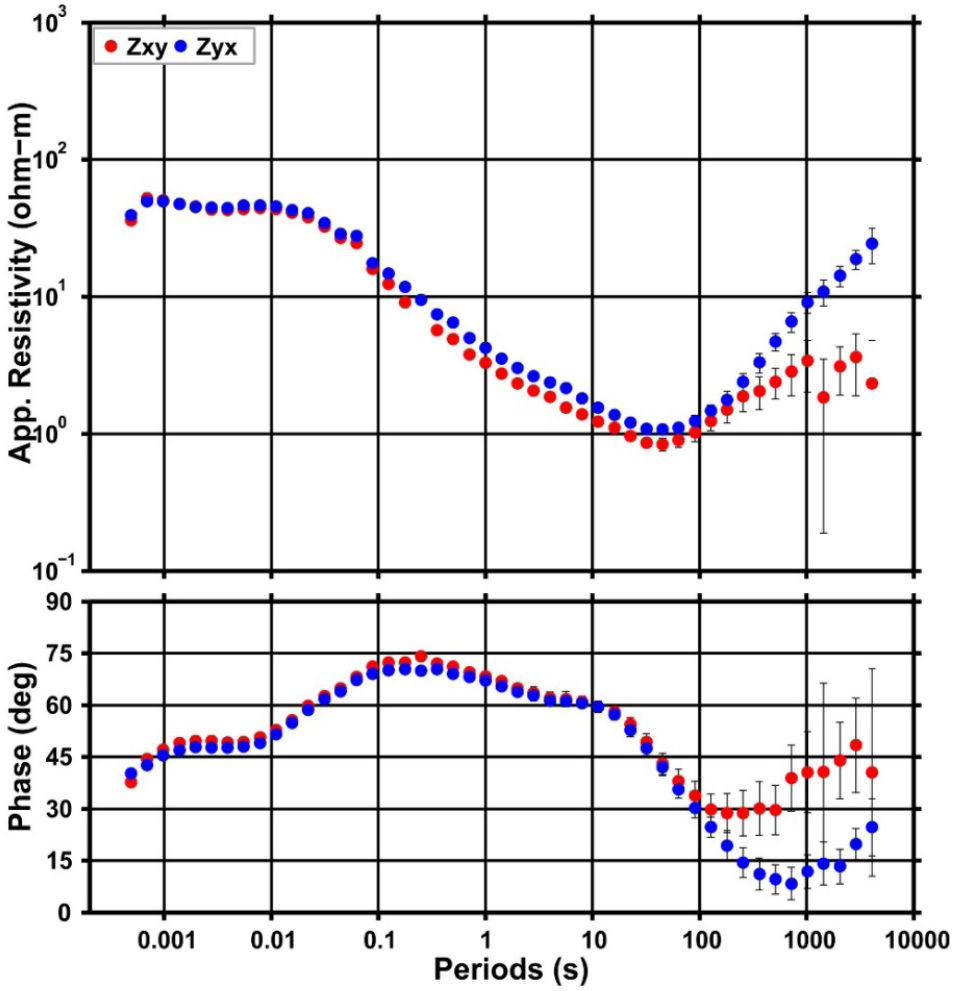


Fig. 5: Exemplary apparent resistivity and phase curves for the three virtual stations recorded at Wittstock (see section 3 for details)

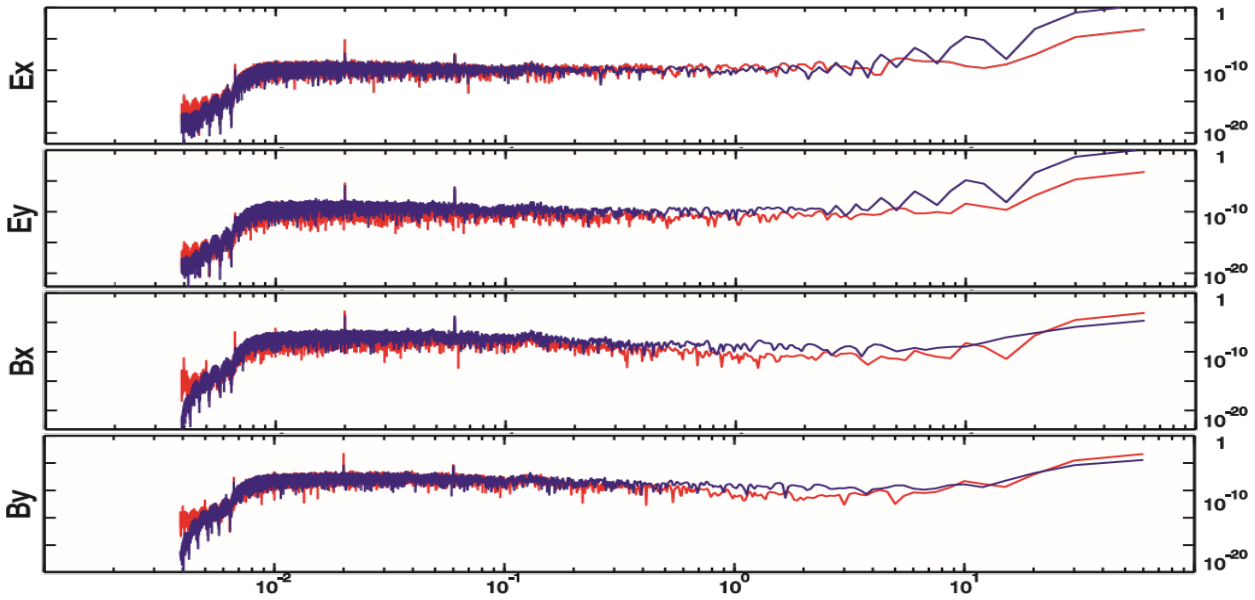


Fig. 6: Comparison of field spectra measured in August 2010 (blue) and December 2011 (red). The red spectra show increased 50 Hz peaks, which could be due to the installation of a solar park. Shown is the frequency contents of a one minute long data segment sampled with 500 Hz.

3 Data availability and access

All data are recorded as time series using two SPAM Mk. IV systems. For ease of use, the data are re-organized as three virtual MT sites, covering a wide frequency range. Data streams can be continuous or in scheduled modes. Fig. 7 summarizes the organisation of the data.

Site 888 records two magnetic field channels (MFS07 coils, Bx, By) and two electric field channels (Ag/AgCl Electrodes, Ex, Ey). The induction coils are operating in the high frequency mode (HF, chopper amplifier switched off). Data are sampled in the kHz range in scheduled mode (e.g. for 10 minutes every hour) and continuously at a lower sampling rate (e.g. 50 Hz). The electric fields for all virtual stations are derived from this continuous data stream.

Site 999 records five magnetic field channels using (MFS06 coils, Bx, By) and a fluxgate magnetometer (Geomagnet, Bx, By, Bz). The induction coils are operating in the low frequency mode (LF, chopper amplifier switched on). Data are sampled continuously, a typical sampling rate is 50 Hz.

Site 991 comprises a 3-component Geomagnet fluxgate magnetometer (Bx, By, Bz) and electric field (Ex, Ey) recordings. Recording is continuous at a sampling rate of 5 Hz.

Site 996 comprises one (or more) continuously recorded data streams using MFS06 induction coil magnetometers (Bx, By, coil switch in LF mode, chopper on) and electric fields (Ex, Ey). Over time, a range of sampling rates were tested (50 Hz, 250 Hz, 500 Hz).

Site 997 records high frequency data which are typically sampled in scheduled mode. Over time, a range of sampling frequencies were tried (2.5 kHz, 5 kHz, 6.25 kHz, 12.5 kHz, 25 kHz). The magnetic fields are recorded with Metronix MFS07 sensors (Bx, By, coil switch in HF mode, chopper off).

Please refer to our webpages to find out in detail how the data were recorded since April 2010 (http://www.gfz-potsdam.de/en/section/geophysical-deep-sounding/servicesinfrastructure/geophysical-instrument-pool-potsdam-gipp/archive/mt-reference-site/). These tables document all changes of sensors, recording instruments, sampling rates, etc. and the tables are regularly updated.

All data files are written in the EMERALD format (Ritter et al., 2015). We also provide computer code and example data demonstrating how to read these data files. The tools are provided as FORTRAN, C and C++ source codes and MATLAB scripts. The interfaces in C++, FORTRAN, and C are described in Ritter et al. (2015).

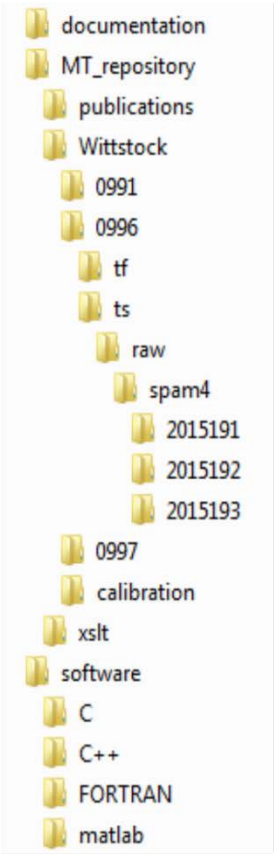
The data files are organized as an extract from the GIPP-MT data repository (see Fig. 8). All files are stored in a specific directory structure, with the data files being sorted into subfolders, each containing data for one day. The naming convention for data folders is YYYYddd: YYYY is the year of recording, ddd specifies the day of data collection (starting with 1 at January 1st and ending with 365/366 at December 31st):

In addition to the data files, meta-data are provided as XML (Extensible Markup Language) formatted files. The contents of the meta-data and the entire data repository can conveniently be viewed by opening the `projetcs.xml` file in the `Wittstock` folder and following the links therein (see Fig. 9). Please note, it may be necessary to enable this functionality in your web browser (in Firefox: enter about:config, set security.fileuri.strict_origin_policy to false).

The `.xml` file is formatted using the extensible stylesheet language transformations in the `xslt` folder. Please make sure to keep the directory structure as all references are made using relative paths.

Period: 08 July 2015 until 09 July 2015 Example							
Site No.		Recorder ID	Sensorbox ID	Recording Mode	Chan. No	Chan. Name	Sensor ID
Internal organisation of data							
888	900	SPAM4 52	SPAM4 131	HF 6.25 kHz 10 min/1 h 250 Hz continuous	4	Ex	Ag/AgCl
					5	Ey	
	907				1	Bx	MFS07 115
					2	By	MFS07 117
999	901	SPAM4 33	Geomagnet 48	LF 2.5 kHz 10 min/1 h 250 Hz, 5 Hz continuous	4	Bx	Geomagnet 48
					5	By	
					6	Bz	
	906		Castle 11		1	Bx	MFS06 6133
					2	By	MFS06 6135
Organisation of data for external use							
991		SPAM4 33	Castle 11	LF 5 Hz continuous	1	Bx	Geomagnet 48
					2	By	
					3	Bz	
		SPAM4 52	SPAM4 131		4	Ex	Ag/AgCl
					5	Ey	
996		SPAM4 33	Castle 11	LF 250 Hz continuous	1	Bx	MFS06 6133
					2	By	MFS06 6135
		SPAM4 52	SPAM4 131		3	Ex	Ag/AgCl
					4	Ey	
997		SPAM4 52	SPAM4 131	HF 6.25 kHz 10 min/1 h	1	Bx	MFS07 115
					2	By	MFS07 117
					3	Ex	Ag/AgCl
					4	Ey	

Fig. 7: Summary of recording modes. Sites 888 and 999 refer to the two SPAM Mk. IV data loggers which are used to record the various sensors. For practical use the data are exported as normal MT sites which include magnetic and electric fields. Site 991 is equipped with a 3-component fluxgate magnetometer, site 996 with Metronix MFS06 induction coil magnetometers and site 997 with MFS07 induction coil magnetometers.



- **documentation**
- **MT_repository**: extract from GIPP-MT data repository
  - **publications**: folder containing relevant references in bibx format
  - **Wittstock**: data of the permanent remote reference site near Wittstock
    - **991**: site folder containing LF data (fluxgate sensor)
    - **996**: site folder containing BB data (MFS06 coils)
      - **ts / raw / spam4 / 201519x** subfolders containing time series data from days 191 - 193 of 2015
    - **997**: site folder containing HF data (MFS07 coils)
    - **calibration**: calibration data for magnetic field sensors
  - **xslt:** folder containing xslt style files to transform xml files to html formatted viewing in web browser
- **software**: folder with sample code to access EMERALD type data files (.RAW/.XTR/.XTRX)
  - **C:** examples in C
  - **C++**: examples in C++
  - **FORTRAN**: examples in FORTRAN
  - **matlab**: examples in matlab

Fig. 8: Example of data file extract.

Details of project Wittstock
(Permanent Remote Reference Station)

Follow this link to view available MT sites .
Follow this link to view available maps .
Follow this link to view pictures .
Follow this link to view publications, conference abstracts, academic theses, etc .

Field experiment:

Country: Germany, region: Brandenburg
Field work lasted from 12-05-2010 to ongoing
Reference latitude: 53.238941
Reference longitude: 12.547573
Reference altitude [m]:127
Show project location in Google Maps.

Responsible scientist:

Oliver Ritter
Telegrafenberg, 14473 Potsdam
oliver.ritter@gfz-potsdam.de
+49 (0)331 288-1257

Project description:

The remote-reference technique is an effective way to improve magnetotelluric data quality by referencing the electromagnetic fields recorded at a local site to simultaneously recorded, undisturbed fields at a remote site. The remote reference approach has become standard for magnetotelluric field work, particularly in areas with high levels of man-made electromagnetic noise; i.e. almost everywhere in central Europe.
Identifying a suitable location for a clean remote site is difficult and time-consuming. Maintaining such a site in addition to normal field operations is expensive and logistically challenging. A permanently installed reference station simplifies MT measurements considerably. After a reconnaissance operation during which several locations all over Germany were tested, we could eventually identify an urban forest near the town of Wittstock in northern Germany as a suitable location for a reference station. A preliminary installation of the reference station was accomplished by mid-2010. The permanent installation in a wooden hut and operating with a range of sensors and sampling rates is available since November 2010.

GFZ participants/contacts in this project:

Gerard Muñoz
Reinhard Klose

We acknowledge contributions from the following funding agencies:

Helmholtz Centre Potsdam - GFZ German Research Centre for Geosciences

Further web resources:

GIPP Data Archive
GIPP-MT

Fig. 9: Viewing projects.xml in the Firefox browser.

4 Citation Information

The magnetotelluric data of the "Wittstock - Permanent MT Remote-Reference Site" is freely availabe upon request and may be used under the Creative Commons Licence (CC-by-sa 4.0 Unported). Please send your data requests to Oliver Ritter (oritter@gfz-potsdam.de).

Recommended citation data report:

Ritter, O., Muñoz, G., Weckmann, U., Klose, R., Rulff, P., Rettig, S., Müller-Brettschneider, C., Schüler, M., Willkommen, G., Eydam, D. (2015) A Permanent Magnetotelluric Reference Station in Wittstock, Germany (Report). Scientific Technical Report 15/09 - Data, GIPP Experiment- and Data, GFZ German Research Centre for Geosciences.
DOI: http://doi.org/10.2312/GFZ.b103-15092

Recommended citation supplementary datasets:

Ritter, O., Weckmann, U., Muñoz, G., Klose, R., Rettig, S., Schüler, M., Müller-Brettschneider, C., Willkommen, G., Rulff, P. (2015) Permanent Magnetotelluric Reference Station Wittstock, Germany (Datasets). GFZ Data Services.
DOI: http://doi.org/10.5880/GFZ.2.2.2015.001

5 References

Chave, A. D. and Jones, A. G., The magnetotelluric method: theory and practice, Cambridge University Press, http://doi.org/10.1017/CBO9781139020138, 2012.

Egbert, G. D., Robust multiple-station magnetotelluric data processing. Geophysical Journal International, 130: 475–496. http://doi.org/10.1111/j.1365-246X.1997.tb05663.x, 1997.

Eydam, D. and Muñoz, G., The Permanent Magnetotelluric Remote-Reference Station, 24. Schmuckler-Weidelt-Kolloqium, Neustadt an der Weinstraße, 19.-23. September 2011.

Gamble, T.D., Goubau, W.M., & Clarke, J., Magnetotellurics with a remote magnetic reference. *Geophysics*, **44(1)**, 53–68, http://doi.org/10.1190/1.1440923, 1979.

Ritter, O., Junge, A. and Dawes, G., New equipment and processing for magnetotelluric remote reference observations. Geophysical Journal International, 132: 535–548. http://doi.org/10.1046/j.1365-246X.1998.00440.x, 1998.

Ritter, O., Klose, R., Weckmann, U., EMERALD Data Format for Magnetotelluric Data, (Scientific Technical Report - Data; 15/08), Potsdam: Deutsches GeoForschungsZentrum GFZ, http://doi.org/10.2312/GFZ.b103-15082, 2015.

ISSN 2190-7110