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The One Second data collection system in Polish geomagnetic observatories

Jan Reda, Mariusz Neska

Institute of Geophysics Polish Academy of Sciences,
ul.Ksiecia Janusza 64, 01-452 Warsaw, Poland
jreda@igf.edu.pl, nemar@igf.edu.pl

ABSTRACT

Over the last half decade, recording of Earth's magnetic field with a sampling rate of 1 second is becoming a new standard in geomagnetic observatories, especially in case of observatories belonging to INTERMAGNET (International Real-time Magnetic Observatory Network). Observatories belonging to our institute, which is responsible for all Polish geomagnetic observatories, have successfully introduced such a 1-sec data collection system. This system consists of a magnetometer, a special digital recorder, and appropriate hardware for processing and sending the data to the data collection centres. We use different types of magnetometers, both the most popular ones equipped with flux-gate sensors and the older ones equipped with Bobrov-type quartz variometers. Both types of magnetometers are characterized by low noise and good long-term stability. One-second data are not only stored on hard disks but also sent to INTERMAGNET GIN (Geomagnetic Information Node) in Edinburgh in real time. The typical real-time delay when providing data to GIN is less than 5 minutes. Therefore such data can be used in real-time applications, e.g. space weather forecasts.

Keywords: Geomagnetic observatory, INTERMAGNET, Real time data, Magnetometer.

INTRODUCTION

There is growing demand for 1 second magnetic variation data. Another important issue is to provide data in near real-time, i.e. with the minimum possible delay. The 1 second data are needed by space physicists studying rapid variations of external origin, such as ULF waves and sudden impulses (*Chulliat et al., 2009*). Near real time data becomes particularly crucial for issues related to space weather forecasting. 1 second data recording in geomagnetic observatories has also become very important because of SWARM and CHAMP satellite missions,to minimize spatiotemporal aliasing, in collating the data with these low-Earth-orbiting magnetic field satellites. Detailed ground-space analyses require 1-second observatory data (*Love and Finn, 2011*).

The only institution in Poland performing standard stationary observations of the geomagnetic field is the Institute of Geophysics, Polish Academy of Sciences (IGF PAS). Such observations consist of a continuous one-second recording of changes of three orthogonal components of the geomagnetic field, and of absolute measurements of the elements of the total geomagnetic field that are carried out regularly.

Currently such observations are conducted in all three observatories of our institute, i.e.:

- The Central Geophysical Observatory at Belsk (BEL, Central Poland),
- The Geophysical Observatory at Hel (HLP, north of Poland),
- The Polish Polar Station at Hornsund (HRN, Spitsbergen)

Routine digital geomagnetic field recordings were initiated in Polish observatories in the first half of the 1980s. Since 1984 Belsk Observatory has begun recording with a digital recorder using tape cassettes developed in our institute. Undoubtedly, this was a turning point compared to analog recording on photographic paper used before. The introduction of digital technology in observatories increased the comfort of observation, reduced the likelihood of human mistakes, and at the same time gave the opportunity of faster sharing of observation data.

A few years after implementation of digital recording techniques, BEL observatory joined the INTERMAGNET in 1992 (*Love and Chulliat, 2013*). HLP and HRN Observatories became members of INTERMAGNET in 1999 and 2002, respectively.

Initially, the sampling period was only 30 seconds with an A/D resolution of 12 bits, and dynamic range ±500 nT. In the following years the digital recording system was modernized. Both resolution of A/D conversion and sampling frequency were increased. A continuous recording with a sampling period of one second began in Belsk observatory in 2002.

INTERMAGNET enjoys a high prestige due to the fact (among others) that it brings together modern observatories providing high-quality data. Joining INTERMAGNET has brought not only prestige to our magnetic observatories, but also has had a positive impact on their development. The best evidence for this is the inclusion of our observatories in the Quasi-Definitive program and the delivery of real-time one-second data to INTERMAGNET.

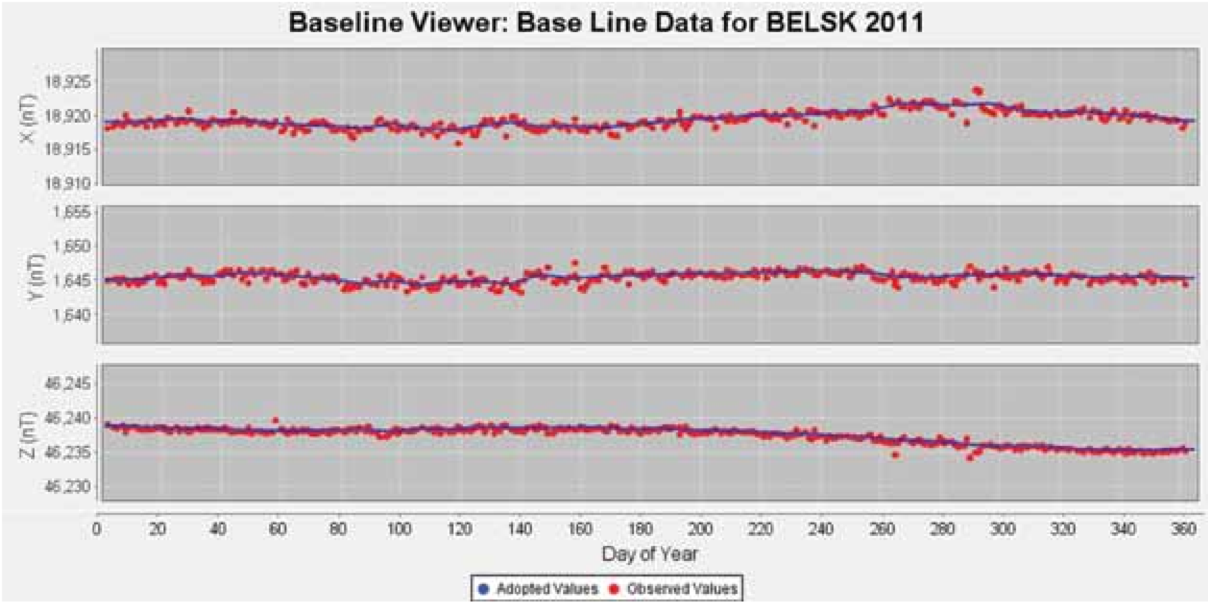

Figure 1. Baselines of PSM magnetometer from the Belsk Observatory.

MAGNETOMETERS

Observations of the Earth's magnetic field consist of absolute measurements and continuous recording of geomagnetic field changes.

Absolute measurements are conducted in the same way in most observatories of the world, i.e., by measuring both inclination (I) and declination (D) by means of a D/I-fluxgate magnetometer, and the total field (F) by a proton magnetometer.

We use the following D/I-fluxgate magnetometers:

- Belsk observatory: ELSEC-810 and GEOMAG-03 (manufacturer: GEOMAGNET).
- Hel and Hornsund observatory: FLUX-9408 (manufacturer: Institute of Geophysics PAS).

For total field measurements, we use PMP-8 and PMP-5 proton magnetometers that have been developed and produced in our institute.

The pool of variometers, i.e., the magnetometers used for recording geomagnetic field variations is more varied. In Belsk and Hel mainly PSM (Polish: Przenona Stacja Magnetyczna, English: portable magnetic station) magnetometers constructed in our Institute are used (*Jankowski et al. 1984*). These magnetometers were produced in small series from the late 1970s to the late 1990s. The basis of their construction is the Bobrov quartz variometer. Bobrov variometers consist of magnets and mirrors suspended on quartz fibres. Originally, such variometers were used for classical recording on photographic paper. In PSM magnetometers, photoelectric converters are added to the classical Bobrov variometers. Due to photoelectric converters and negative feedback, PSM magnetometers produce analog signals proportional to changes of the magnetic field. Even today the metrological parameters of PSM magnetometers are only minimally lower than those of the best flux-gate magnetometers. They have a good long-term stability and low noise. The disadvantages of PSMs are their complicated installation and service, large dimensions and weight, and considerable power consumption. Figure 1 illustrates the stability of a PSM magnetometer.

Standard PSM magnetometers have a 0.3 Hz analog low-pass filter, but in the exemplars used in our observatories the cut-off frequency has been increased up to 3 Hz. However, it should be noted that the sampling of analog signal is carried out with a frequency of 12,800 Hz.

Nowadays, we use fluxgate-type magnetometers in the Polish Polar Station Hornsund at Spitsbergen for the measurement of field changes. For the primary data set, a modern GEOMAG-02 magnetometer manufactured by the Ukrainian company GEOMAGNET is deployed. An older one (LEMI-03, also Ukrainian, made by Centre of the Institute of Space Research (*Korepanov et al., 1998*) is used as a backup magnetometer.

The most important reasons for the use of GEOMAG-02 magnetometer are the following:

- Low noise level and good stability,
- Cardan-suspended variometer sensor, which is very important in arctic conditions because of freezing / unfreezing ground during autumn and spring.
- Friendly use by the rotating shift personnel.
- The magnetometer is equipped with both analog output and flash memory-based digital data logger.

The noise characteristics of GEOMAG-02 magnetometer is shown in Figure 2.

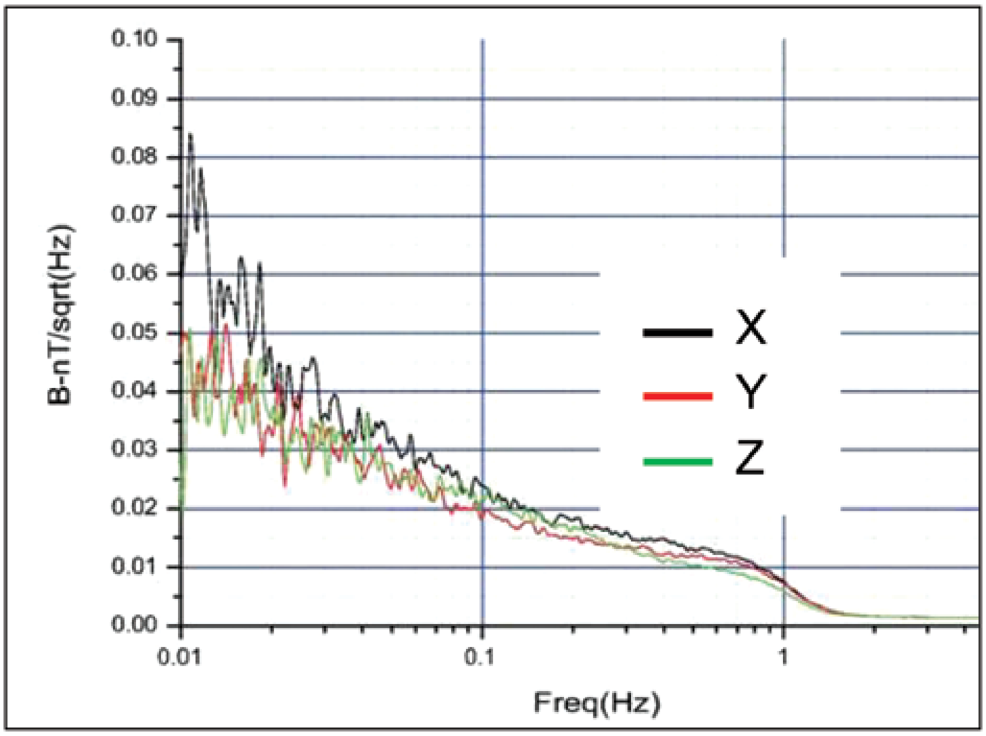

Figure 2. Noise characteristics of GEOMAG-02 magnetometer.

DATA ACQUISITION SYSTEM

All geomagnetic observatories belonging to IGF PAS have very similar data acquisition systems with regard to:

- conversion of analog signals from magnetometers to digital format,
- data processing consists of generating and updating binary and metadata files,
- conversion of data to file formats required by INTERMAGNET or cooperating institutions,
- sending data to data centres,
- providing real-time data in graphical form on the Institute's webpage.

A block diagram of such a system is shown in Figure 3.

One of the basic parts of the data acquisition system is the Network Data Logger (NDL) for geomagnetic field changes recording. The basic parameters of this NDL logger are listed in Table. 1.

Both the setting of recording parameters and the data transfer from the NDL data logger are possible via ethernet interface. The recorded data is stored on a compact flash card and access to it is carried out via ftp protocol; it is typically defined as a cron job (scheduled every minute). Short raw NDL data files are processed and archived in binary format. Meta data information (scale values, base of registration, and many other parameters) for each observatory are stored in text files. Binary and metadata files are input to further processing. In the next steps the data is converted to many formats for different purposes. The most important of them are listed below:

- One-second IAGA2002 format (INTERMAGNET, Regional Warning Center - Space Research Centre, Polish Academy of Science, and as a reference for many field measurement campaigns by induction sounding methods, e.g., *Neska 2007*)
- One-minute IMFV1.23 format (INTERMAGNET, http://rtbel.igf.edu.pl)
- One-second IAGA format (IMAGE project, Hornsund only)
- One-second EMMA binary format (PLASMON project)

IAGA2002 files are sent to INTERMAGNET every minute whereas reported one-minute IMFV1.23 files are sent every 5 minutes. In case of one-second data it is very important to send data to international data centers with the shortest delay possible. An example statistics for the delay between sent data and real time is shown in Figure 4. One-second data is used, e.g., for space weather forecast. Quasi-definitive and definitive one-minute data are prepared manually (e.g., final bases are adopted and peaks are removed) and sent to INTERMAGNET after the end of every month and year, respectively. These software utilities are compatible only with the in-house built NDL logger at present. The DDF format is also not a standard one. Therefore, the details of software do not have wider applicability. Adaptation of this software to run on other hardware platforms is yet to be developed.

Table 1. Main parameters of NDL data loggers

AD conversion	sigma-delta 24 bits
Timing	GPS receiver
Analog inputs	6 channels, ±10V
Sampling periods	1.25ms, 2.5ms, 5ms , 10ms, 20ms, 50ms, 100ms, 200ms, 500ms, 1s, 2s, 5s, 10s, 20s, 30s, 60s
Internal sampling of analog signal	12,800 per second
Analog filtration	Anti-aliasing low-pass filter 200 Hz, 18 dB/oct
Digital filtration	FIR - low-pass filter, IIR - high-pass filter
Mass storage device	Compact Flash
Communication interface and protocols	Ethernet, TCP/IP, ftp
Power supply	12V DC / 300 mA

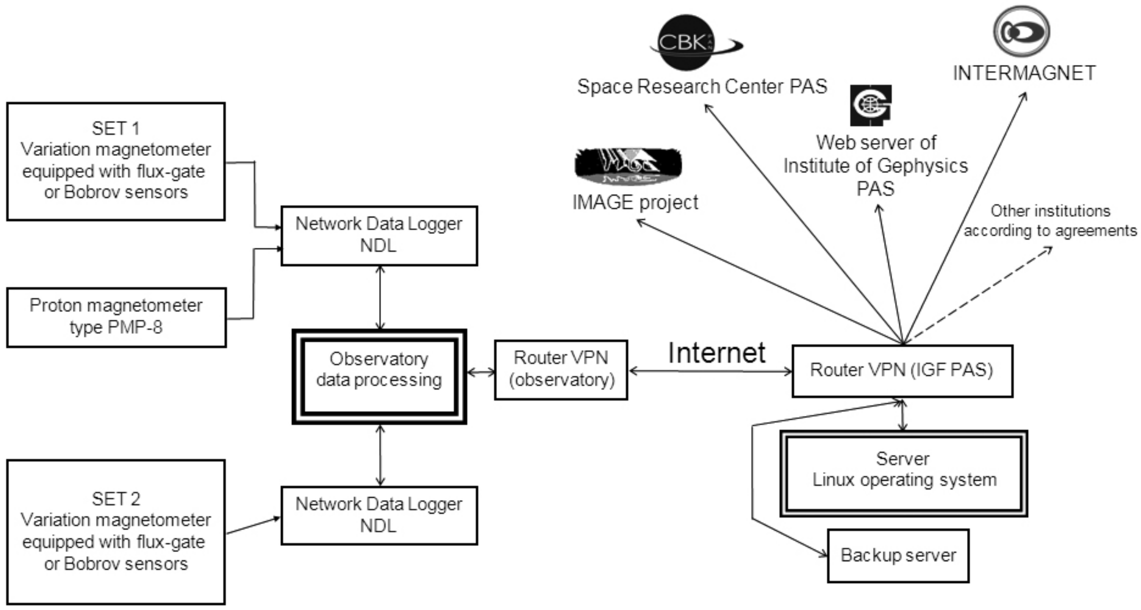

Figure 3. Block diagram of data acquisition system

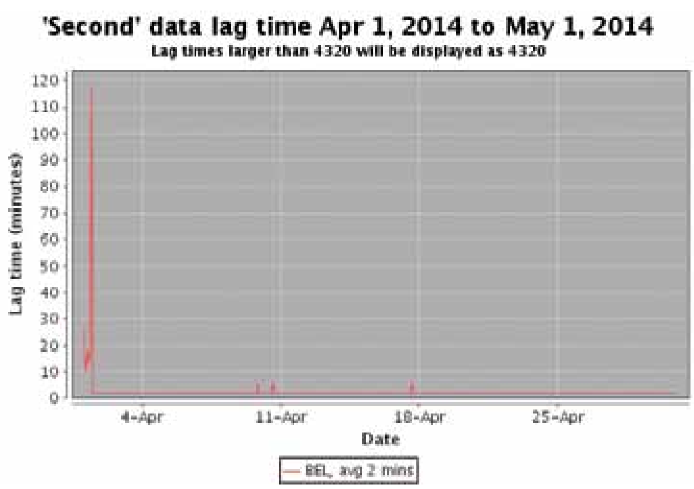

Figure 4. Lag time (Belsk/April 2014) defined as the amount of time between the current time and the time of the latest data sample received by the GIN. This plot has been automatically generated by web application working on Edinburgh INTERMAGNET Geomagnetic Information Node.

SUMMARY

All three geomagnetic observatories of the Institute of Geophysics, Polish Academy of Sciences, participate in and contribute to the INTERMAGNET. They are not uniformly equipped with the same magnetometers. However, the metrological parameters of the magnetometers used by them are similar; they are characterized by low noise and good stability. All observatories deliver their one-second data in real time. The average lag time for sending one-second data to INTERMAGNET is two minutes provided that the internet works properly.

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