VERIFICATION OF THE TIME ACCURACY OF A MAGNOMETER BY USING A GPS PULSE GENERATOR

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ABSTRACT

The time accuracy of geomagnetic data is an important specification for one-second data distributions. We tested a procedure to verify the time accuracy of a fluxgate magnetometer by using a GPS pulse generator. The magnetometer was equipped with a high time resolution (100 Hz) output, so the data delay could be checked directly. The delay detected from one-second data by a statistical method was larger than those from 0.1-s- and 0.01-s-resolution data. The test of the time accuracy revealed the larger delay and was useful for verifying the quality of the data.

Keywords: Geomagnetic field, One-second data, Time accuracy, Fluxgate magnetometer

1 INTRODUCTION

Some magnetic observatories have been exchanging one-minute geomagnetic field data in near real time as part of a program of the International Real-time Magnetic Observatory Network (INTERMAGNET). Recently, however, one-second data distributions and their requirements have become a hot issue. For example, requirements for resolution, absolute measurement accuracy, noise levels, and so on have been discussed among the relevant participants in INTERMAGNET. A standard of time accuracy is one of the outstanding problems, but no common method to determine the time accuracy of the output of a magnetometer has been established.

Rasson (2009) examined the time accuracy of a magnetometer with magnetic signals generated by a GPS pulse generator. To detect the delay of a signal that is much smaller than the time resolution, a one-second, statistical method was used to calculate the time accuracy.

The Japan Meteorological Agency (JMA) has been recording one-second data and 0.1-s-resolution field data (0.1 second data) at magnetic observatories at Kakioka, Memambetsu, and Kanoya (Minamoto, 2009). In addition, a new fluxgate magnetometer with a 100 Hz sampling channel was introduced in 2010 at Kakioka, which allows us to directly investigate the delay of its recorded signals with a GPS pulse generator.

In this paper, we describe the procedure and present the results of a verification of the time accuracy of the magnetometer by using a GPS pulse generator.

2 EXPERIMENTAL

The GPS pulse generator (Figure 1) was made by the Geomagnetic Laboratory of Natural Resources Canada (www.nrcan.gc.ca), Ottawa, Canada. The pulse generator system consists of a GPS receiver, microcontrollers, and a pulse generator. This system outputs rectangular pulses synchronized with GPS signals. The cycle time of the rectangular pulses can range between 2 and 3,276,810 s.

Figure 1. The GPS pulse generator

Once a coil is connected to the pulse generator, the magnetometer gives out precisely timed magnetic signals. According to the technical documentation of the GPS generator, the potential in the coil reaches 80% of its maximum at approximately 5×10^{-3} s and drops to 20% of its maximum at approximately 2.4×10^{-5} s compared to the top of the second with a coil of 626 mH and 154.4 Ohms. To produce the magnetic signals, we used a simple 44-turn coil, which was handmade (Figure 2) with a diameter of 116 mm, a length of 126 mm, and an inductance of 5.5×10^{-5} H was measured by an LCR meter (Inductance (L), Capacitance (C), and Resistance (R)). A resistance of 460 Ohms was inserted to adjust the current. The inductance of the coil was so small that the time lag between the direct current rise and the magnetic signal was negligible. It dropped to 20% of its maximum current in approximately 1.9×10^{-7} s.

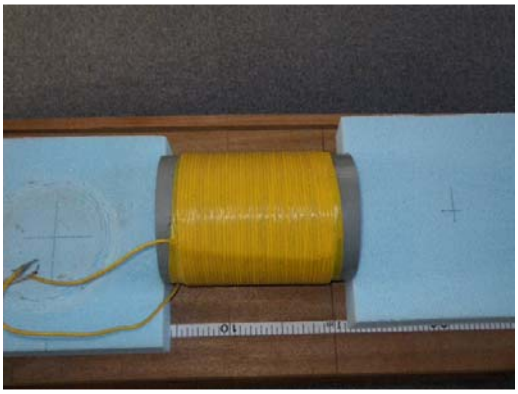

Figure 2. Coil used for the test

To estimate the volume of magnetic signals obtained by the coil and pulse generator, a preliminary test was undertaken. When the coil was placed 50 cm south of the center of the magnetometer sensor (Figure 3), the pulse changed the output of the magnetometer by about 1.1–1.3 nT for the H component and 0.4 nT for the Z component. The output of the D component scarcely changed.

Figure 3. Preliminary test

After that preliminary test, we sent the precisely timed magnetic signals to a new, highly sensitive fluxgate magnetometer on 17 August 2010 (Figure 4). The magnetometer had made a trial run and no noise was included in the published data during a trial run of the magnetometer. The periods adopted for the GPS synchronizing pulses were 4, 8, and 16 seconds.

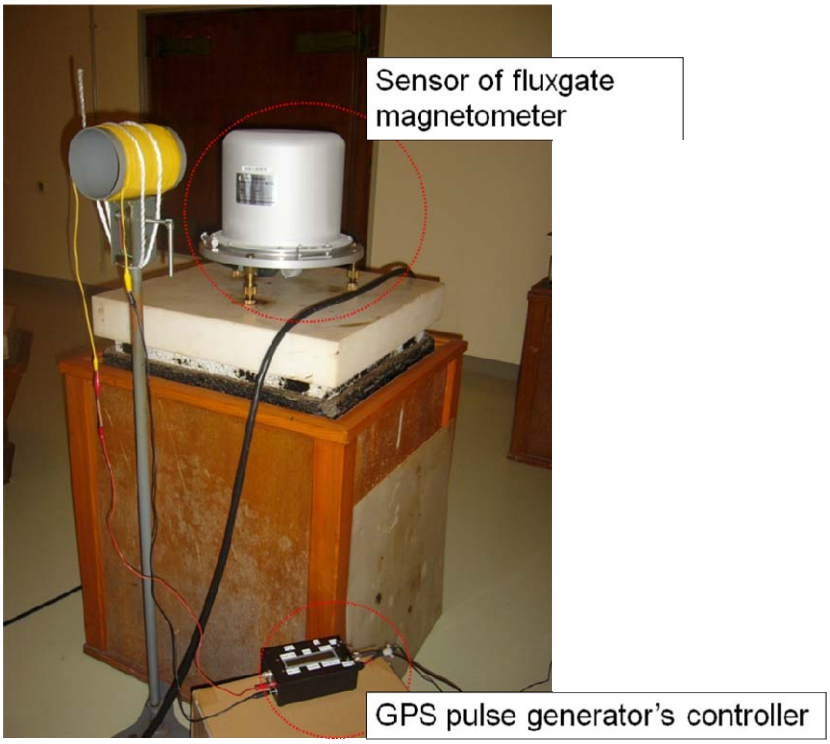

Figure 4. Setup of the timing accuracy test of the new fluxgate magnetometer. The coil was mounted north of the sensor.

3 RESULTS AND DISCUSSION

The calculated delays of one-second values were determined by the magnetometer from 1000 waves by using a method based on the technique of linear least squares parameter estimation (Rasson, 2009). The results show that the delay of the recording of the fluxgate magnetometer was 0.385 second. It was the same for each period (4, 8, and 16 seconds).

As mentioned above, the new magnetometer can obtain magnetic data with a higher time resolution, so the delay of the recorded signals could be investigated directly. Figures 5 and 6 show the changes of the 0.1second values, and Figure 7 shows the changes of the 0.01second values.

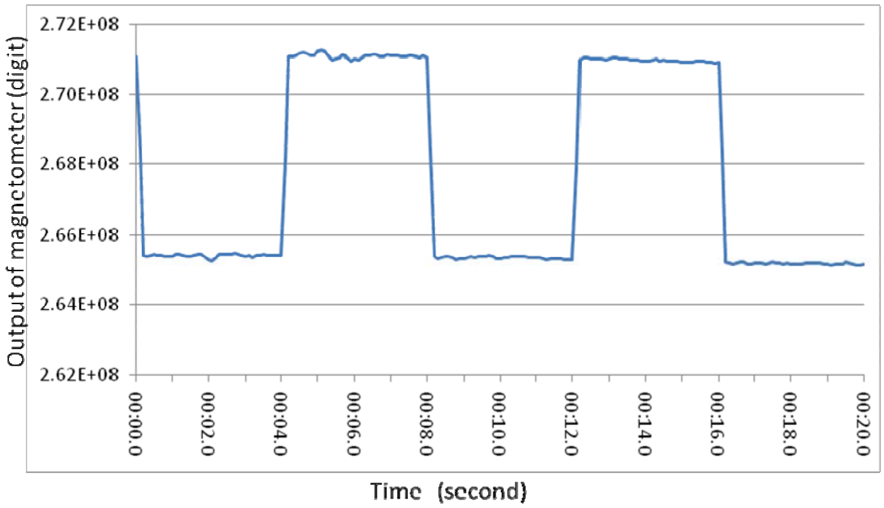

Figure 5. 0.1 second values of the X component output of the magnetometer with magnetic signals obtained by the GPS pulse generator. The period of pulsation was 8 seconds. The output (vertical axis) has not been converted into magnetic flux density (nT).

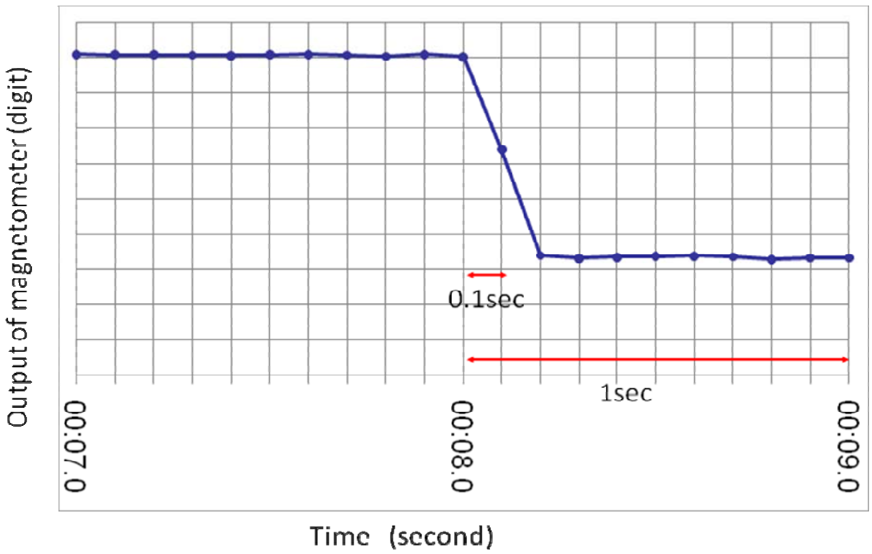

Figure 6. Enlarged plot of Figure 5 near the digital switching

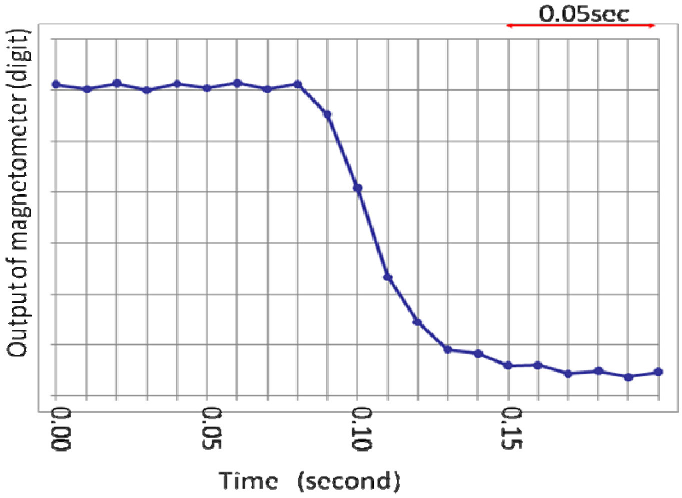

Figure 7. 0.01second values of the X component of the geomagnetic field with magnetic signals obtained by the GPS pulse generator. The period of pulsation was 8 s. The output of the magnetometer (vertical axis) has not been converted into magnetic flux density (nT).

The enlarged plot of the 0.1 second values (Figure 6) shows that the digital switching occurred between 0.0 and 0.2. While the 0.01 second values (Figure 7) indicate that the decline of the output signal started about 0.09 second later on the second, it took about 0.05 s to complete the switching. This delay is much smaller than that obtained from one-second data (0.385 second). Although the plot of 0.01 second value is indistinct due to the magnetometer's built-in filter, the delay should not be seriously affected. We could not identify the reason why a notable difference in the delay is observed.

Analog-to-digital conversion in the magnetometer occurs for each component simultaneously at 250 Hz. 0.01-second values are calculated from two or three digital values obtained at 250 Hz. A 0.1-second value at time *t* is calculated from 10 0.01-second values between *t* and *t*+0.1. Likewise a 1-s-resolution value at t is determined from 10 0.1-s-resolution values between *t* and *t*+1.

We suspect that the difference in the delay is caused by the procedure of forming 1-s-resolution data. This serious discrepancy in the verification of time accuracy is obviously unacceptable. We made an exhaustive investigation and found that the problem can probably be traced to the built-in software. The error will be fixed soon.

4 SUMMARY

We tested a procedure intended to verify the time accuracy of a fluxgate magnetometer by using a GPS pulse generator. The delay of the recorded magnetic field 1-s-resolution data was calculated to be 0.385 second by using a method based on a linear least squares parameter estimation while 0.1 second data and 0.01 second data revealed that the delay is about 0.1 second.

The origin of the difference in the delay measurements has yet to be determined.

5 ACKNOWLEDGEMENT

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6 REFERENCES

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