



INTERMAGNET

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AN INSTRUMENT PERFORMANCE AND DATA QUALITY STANDARD FOR INTERMAGNET ONE-SECOND DATA EXCHANGE

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With the advent of developments in instrumentation, data acquisition and data dissemination, an increasing number of observatories are producing a filtered one-second data product in addition to traditional one-minute data, hourly means, daily means, monthly means and annual means. An INTERMAGNET survey of the user community in 2005 concluded that there is a desire for one-second data to be made available through the

INTERMAGNET network and that, as is the case for one-minute data, a minimum standard of instrument performance and data quality should be set for definitive one-second data. Here, the INTERMAGNET Observatories & Standards Subcommittee introduces such a one-second data standard resulting from consultation with the scientific community and instrument developers.

The parameters listed below describe the specifications of a complete observatory system for a one-second vector data set including recording environment, magnetometer, and data processing procedure:

General specifications

- Time-stamp accuracy: 0.01s
- Phase response: Maximum group delay ± 0.01 s
- Maximum filter width: 25 seconds
- Instrument amplitude range:
 - $\geq \pm 4000$ nT High Latitude
 - $\geq \pm 3000$ nT Mid/Equatorial Lat.
- Data resolution: 1pT
- Pass band: DC to 0.2Hz

Pass Band Specifications [DC to 8mHz (120s)]

- Noise level: ≤ 100 pT RMS over 10 minutes
- Maximum offset error (cumulative error between absolute observations): ± 2.5 nT
- Maximum component scaling & linearity error: 1%
- Maximum component orthogonality error: 2mrad
- Maximum Z-component verticality error: 2mrad

Pass Band Specifications [8mHz (120s) to 0.2Hz]

- Noise level: ≤ 10 pT/ $\sqrt{\text{Hz}}$ at 0.1 Hz
- Maximum gain/attenuation: 3dB

Stop Band Specifications [≥ 0.5 Hz]

- Minimum attenuation in the stop band (≥ 0.5 Hz): 50dB

Auxiliary measurements

- Compulsory full-scale scalar magnetometer measurements with a data resolution of 0.01nT at a minimum sample period of 30 seconds.
- Compulsory vector magnetometer temperature measurements with a resolution of 0.1°C at a minimum sample period of one minute.

General Specifications

The consensus of the scientific community survey was that one-second data should be accurately time-stamped and the instruments have linear phase response. Hence, a maximum time-stamp error has been specified and the phase response quoted in terms of a maximum group delay, which limits the non-linearity of the phase. Data samples may be time-shifted to correct for latency (e.g. instrument response and filter delay) provided that the system phase response is met. The quoted instrument ranges are inherited from the INTERMAGNET one-minute specification, while a data format resolution is specified to reduce quantisation noise and a maximum filter width is set to minimise the time extent of the system response to a step input i.e. filter ringing.

Pass Band Specifications [DC to 8mHz (120s)]

Observatories moving from absolute one-minute recordings to absolute one-second recordings will require to monitor over not only a larger frequency band but, due to the spectrum of the natural magnetic field, also a larger dynamic range. To meet these stringent measurement requirements yet ensure that the limitations on the instrumentation are realistic, the pass band has been split into two: the existing INTERMAGNET one-minute data band (DC to 120s) and the extended band (8mHz to 0.2Hz). For the low frequency band (DC to 120s), there is a higher system noise level limit than the high frequency band but more constraints on parameters affecting the absolute accuracy, such as sensor orthogonality errors, scale and offset errors. The offset error is expressed as a maximum error from all sources (including instrument and thermal drift) between absolute observations without specifying a minimum frequency of absolute observations, allowing for infrequent observations where baseline stability is good.

Pass Band Specifications [8mHz (120s) to 0.2Hz]

In the high frequency band of the pass band (8mHz to 0.2Hz), the noise level is set at a lower level to ensure sufficient resolution of low amplitude signal in this band of the natural geomagnetic spectrum. Since absolute signal amplitude is not as critical in this band as it is in the low frequency band, and to allow for instrument roll-off with sufficient attenuation in the stop band, the maximum signal gain/attenuation is specified at a less stringent 3dB in the high frequency band.

Stop Band Specifications [≥ 0.5 Hz]

The stop band is defined at the Nyquist, allowing for a sufficiently wide transition band to set a high stop-band attenuation to attenuate typical natural signal amplitude to meet the noise specification for aliased signal in the pass band. This specification alone will not sufficiently attenuate large amplitude signal, such as 50/60 Hz, hence it is recommended to separately attenuate non-natural, large-amplitude signals above the Nyquist.

Auxiliary measurements

Another modification over the INTERMAGNET specification for one-minute data is the requirement for auxiliary measurements from an absolute scalar magnetometer and monitoring of the variometer temperature for the purpose of quality control.

The set of standards described here will be defined and, where possible, tested to be the minimum quality requirements for definitive one-second data to be distributed via the INTERMAGNET web site and DVD.

It is important to note that, whilst INTERMAGNET encourages observatories to participate in the exchange of one-second data, the INTERMAGNET network will continue to distribute one-minute data and existing definitive one-minute standards are unaffected.

Further details on the INTERMAGNET one-second standard are provided in INTERMAGNET Discussion Document 20, a copy of which can be obtained from a member of the Observatories & Standards Subcommittee or by request from secretary@intermagnet.org.

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