Suspended dIdD for Observatories

In the past, magnetic observatories relied on a combination of Overhauser, fluxgate and theodolite instruments for obtaining measurements. GEM then introduced the dIdD (delta Inclination / delta Declination) system for high precision results.

Now, the dIdD has been enhanced significantly with the development of the Suspended dIdD system (shown below).

The Suspended dIdD comprises a revolutionary small diameter (250 mm), spherical Overhauser sensor with a bi-directional set of bias coils. Data is acquired directly to a GEM Overhauser magnetometer.

Simplifying Magnetic Measurements

The Suspended dIdD simplifies the set-up of magnetic observatory installations by eliminating the need for fluxgate magnetometers and thermal insulating structures. In addition, the new system minimizes ongoing system calibrations, which, in turn, frees personnel to concentrate on more essential tasks such as interpreting and understanding data.

These important new benefits are achieved through system design considerations, including:

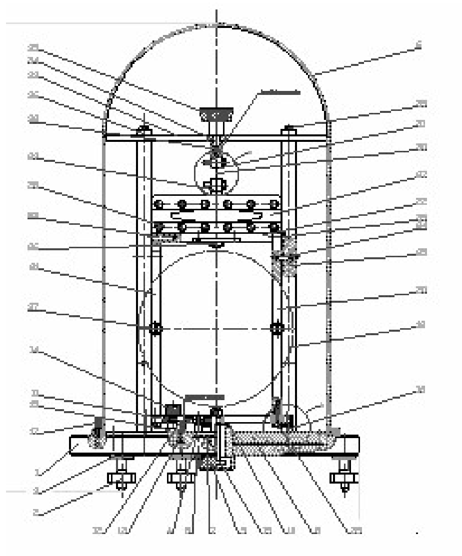
- Temperature coefficients that reduce drift to less than 0.1 nT / °C (compared with 0.5 nT / °C for high-end fluxgate magnetometers)
- Physical suspension of the Overhauser sensor (shown experimentally to contribute to reduced drift)
- Long term drifts that are less than 2 nT / year – matching or exceeding the best component measurement at any observatory

Ultimately, the system also exceeds specifications set by Intermagnet - the global network of observatories monitoring the Earth's magnetic field (www.intermagnet.org).

GEM's Suspended dIdD is implemented in the world's newest magnetic observatory as the sole instrument for continuous, stable measurement. The system will be calibrated by theodolite on a reduced basis (i.e. in comparison with older technology installations).

Suspension System

The new dIdD magnetometer uses a set of two beryllium / bronze springs for suspension. These springs are oriented perpendicular to each other for stability.



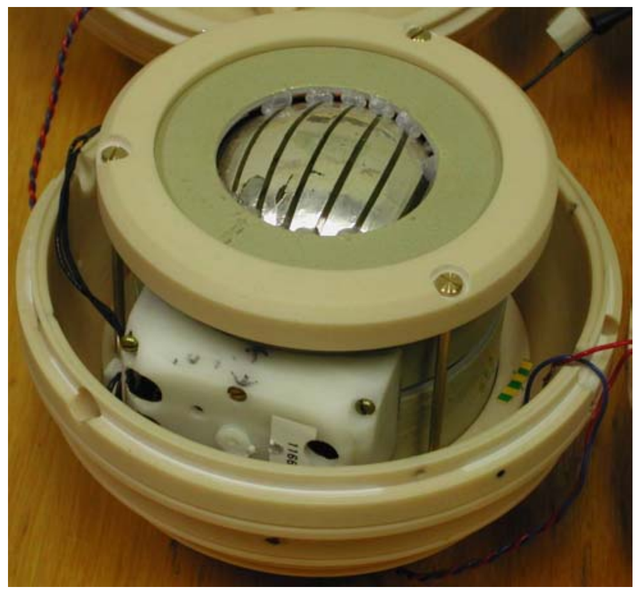
Even if the base or suspending part is tilted, the two springs ensure that the coil remains in the same position. This also applies to the tier or pedestal on which the system rests.

The ultimate benefit is that the axis between the coils and the planes of measured magnetic fields does not change – ensuring precision measurement.

As mentioned previously, another benefit of the suspension system is an improvement in the temperature coefficient of the dIdD – a phenomenon that has been observed experimentally and is still under investigation for its potential to further improve drift.

Sensor and Coils

A key engineering design consideration was development of Overhauser sensors that were optimally shaped to better interact with the magnetic fields surrounding the coil. Below is shown an image of the revolutionary circular sensor that was implemented in the Suspended dIdD.



The external casing is impact resistant plastic. An upper support plate ensures that there is no movement of the sensor.

The smaller sized sensor has advantages in terms of robustness (i.e. it is more durable than previous generations of larger, cylindrical sensors).

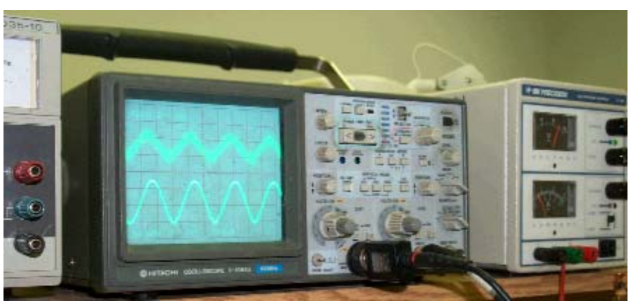
It is also easier to suspend and can be transported more readily. An immobilizing mechanism is provided to ensure that there is minimal shift and to protect the system from damage during transport.

Overhauser Principles

GEM's Overhauser magnetometer instrument is the heart of the Suspended dIdD system.

In a standard Proton magnetometer, current is passed through a coil wound around a sensor containing a hydrogen-rich fluid. The auxiliary field created by the coil (>100 Gauss) polarizes the protons in the liquid to a higher thermal equilibrium.

When the current, and hence the field, is terminated, polarized protons precess in the Earth's field and decay exponentially until they return to steady state. This process generates precession signals that can be measured as described below.



Overhauser magnetometers use a more efficient method that combines electron-proton coupling and an electron-rich liquid (containing unbound electrons in a solvent containing a free radical). An RF magnetic field -- that corresponds to a specific energy level transition -- stimulates the unbound electrons.

Instead of releasing this energy as emitted radiation, the unbound electrons transfer it to the protons in the solvent. The resulting polarization is much larger, leading to stronger precession signals.

Both Overhauser and proton precession, measure the scalar value of the magnetic field. The magnetic flux density is proportional to the product of the precession frequency and gyromagnetic constant (which is known to a high degree of accuracy). Overall reading quality is determined using signal amplitude and decay characteristics.

Suspended dIdD Measurement

The Suspended dIdD is a vector magnetometer for continuous monitoring of the inclination, declination and total intensity of the Earth's magnetic field. It is this combination of measurements that sets it apart from fluxgate instruments (i.e. fluxgates only provide inclination and declination – an Overhauser or Precession unit is needed to measure total intensity).

GEM's dIdD employs a mutually orthogonal coil system that measures one unbiased and four biased values of total magnetic fields. The axes of the coil system are arranged so that the axes of the mutually orthogonal coils are themselves perpendicular to the Earth's magnetic field vector, **F**, in the geomagnetic horizontal and vertical meridian planes.

Initially, equal and opposite currents are sequentially introduced in to the Inclination (I) coil – oriented perpendicularly to **F**. These deflection fields lie in the local geomagnetic planes. The resultant deflected values of **F** ($\mathbf{I_p}$ and $\mathbf{I_m}$) are recorded by the Overhauser magnetometer. The undeflected value is also recorded.

Then, equal and opposite currents are sequentially introduced into the Declination coil (D) which is also perpendicular to **F**. The D deflection fields lie in the horizontal plane in the magnetic East – West direction. Resultant deflected values of **F** ($\mathbf{D_p}$ and $\mathbf{D_m}$) are recorded.

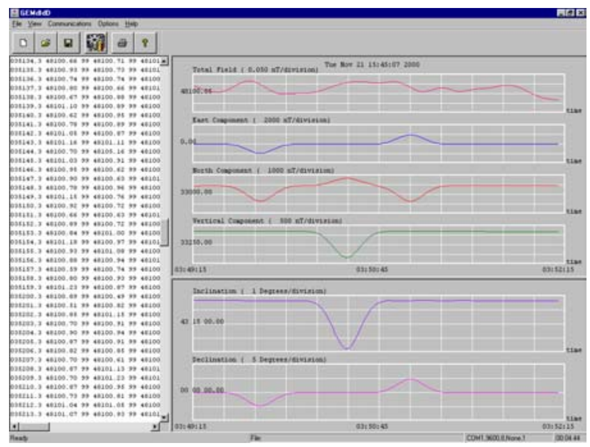
A simple algorithm is used to determine the instantaneous angular differences between the coil axes and the direction of the Earth's vector, **F**. These angular differences are dI and dD.

The X, Y and Z components are computed by adding dI and dD to baseline values of Inclination and Declination for the coil system. (Baseline values are determined from absolute measurement.) The results are instantaneous Inclination and Declination values of **F**.

Data Acquisition & Display Software

GEM provides a custom data acquisition and display software system with its Suspended dIdD vector magnetometer.

The software displays analog data versus time in a column to the left of the software screen. This enables easy monitoring of basic system functions.



Separate charts are displayed to the right and are arranged in sequence with Total Field, East, North and Vertical components in a designated plotting area. Below are Inclination and Declination charts that provide easy visualization of changes in inclination and declination.

Vertical and horizontal scales are automatically calculated to ensure that data is displayed correctly within each plotting area. Or, the user can adjust plotting scales. The displayed profile can be scrolled both horizontally and vertically. Changes to the display are made through an easy-to-navigate menu system. Calculated and raw values are saved automatically to file.