Understanding the UKRAA Magnetometer

1. Introduction

This paper describes what the UKRAA two axis Magnetometer measures and how to interpret the measurements by comparison with professional data from the British Geological Survey.

2. Magnetometer Output

The UKRAA Magnetometer is designed to be aligned orthogonally (at 90°) to the Earth's magnetic field. The circuit board is positioned to face magnetic North and adjusted in the vertical plane to match your latitude. It then records changes to the magnetic field as the alignment between the fixed Magnetometer and the magnetic field changes over time.

When the Magnetometer is aligned with the magnetic field the output of the sensor is at a null point in its response.

The Magnetometer output voltage is 0-5 V with the centre point at 2.5 V. Change in the alignment of the magnetic field in one direction causes the output to fall towards 0V and change in the other direction causes the output to increase towards 5 V. When the horizontal axis is pointing to magnetic North the output is 2.5 V this changes as the Magnetometer is rotated towards the East or West. The vertical axis works in a similar way.

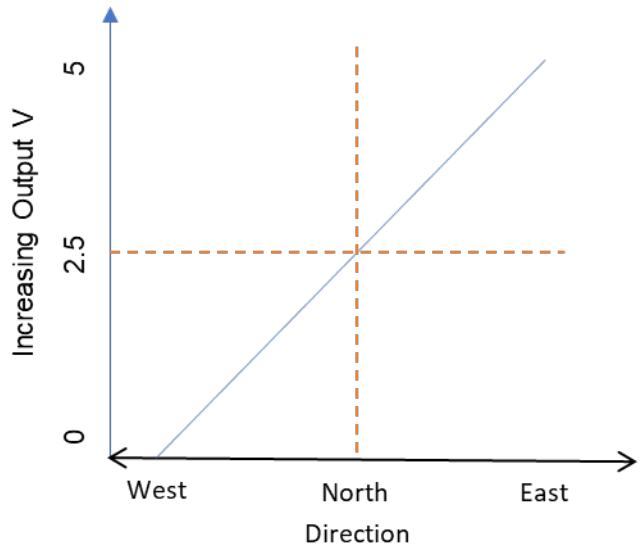

Figure UKRAA Magnetometer variation in output voltage due to East-West orientation[1]

It is important to understand that the Magnetometer is only sensitive to the alignment with the magnetic field, not the strength of the field. A small change in the alignment will produce a change in the output voltage. A change in the magnetic field strength will not result in a change in the output voltage. This is because the alignment between the Magnetometer and the magnetic field has not changed.

1 *The author*

3. World Magnetic Model Coordinate System

At any point on Earth the magnetic field has an intensity (denoted F) and a direction. Think of the Earth as a simple bar magnet.

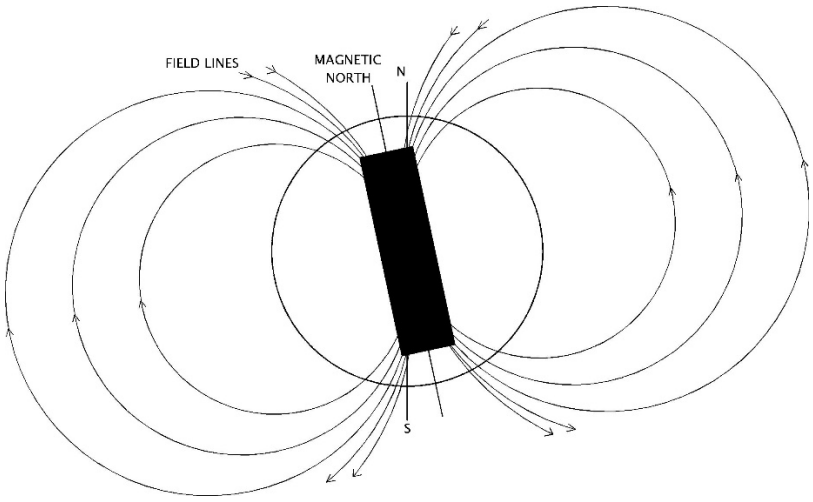

Figure Earth's magnetic field[2]

At the equator the field is parallel to the ground and at the magnetic poles it points straight down. The angle between the horizontal ground and the magnetic field can be measured and is called the magnetic inclination or dip angle (denoted I). The magnetic field is not aligned with the geographic North Pole and the angle between the magnetic field and geographic North can be measured. This is the magnetic declination or variation (denoted D). Users of UK Ordnance Survey maps will be familiar with allowing for this when taking compass bearings.

There is a standardised coordinate system used to measure and study geomagnetism.

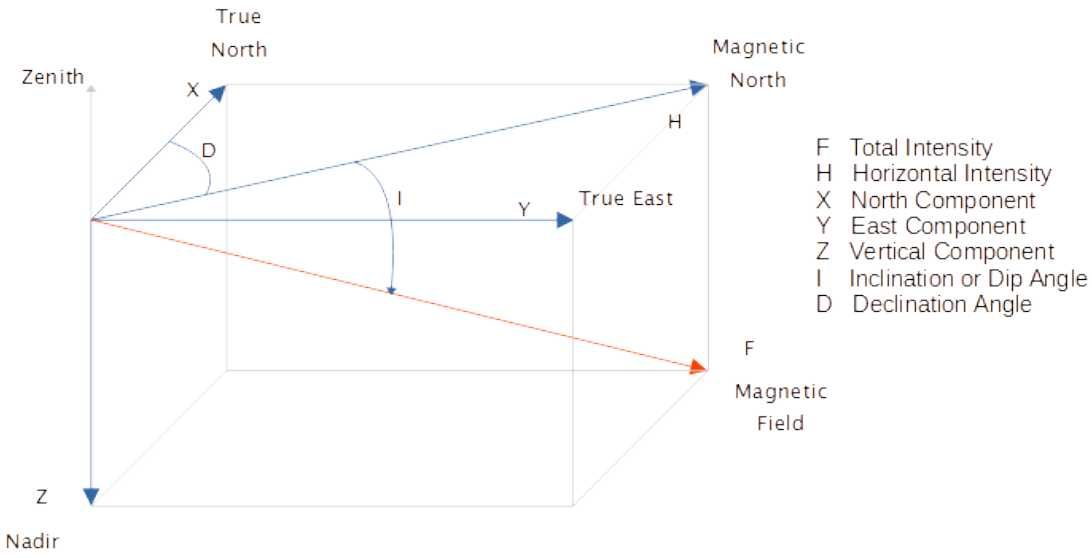

Figure Magnetic Coordinate System[3]

2 *Extract from UKRAA Magnetometer User Manual*

The geomagnetic field vector, is described by the orthogonal components *X* (northerly intensity), *Y* (easterly intensity) and *Z* (vertical intensity, positive downwards); total intensity *F*; horizontal intensity *H*; inclination (or dip) *I* (the angle between the horizontal plane and the field vector, measured positive downwards) and declination (or magnetic variation) *D* (the horizontal angle between true North and the field vector, measured positive eastwards).

4. Aligning the UKRAA Magnetometer

When the Magnetometer is aligned orthogonally to the field vector (denoted F) the two Magnetometer axes are shown below.

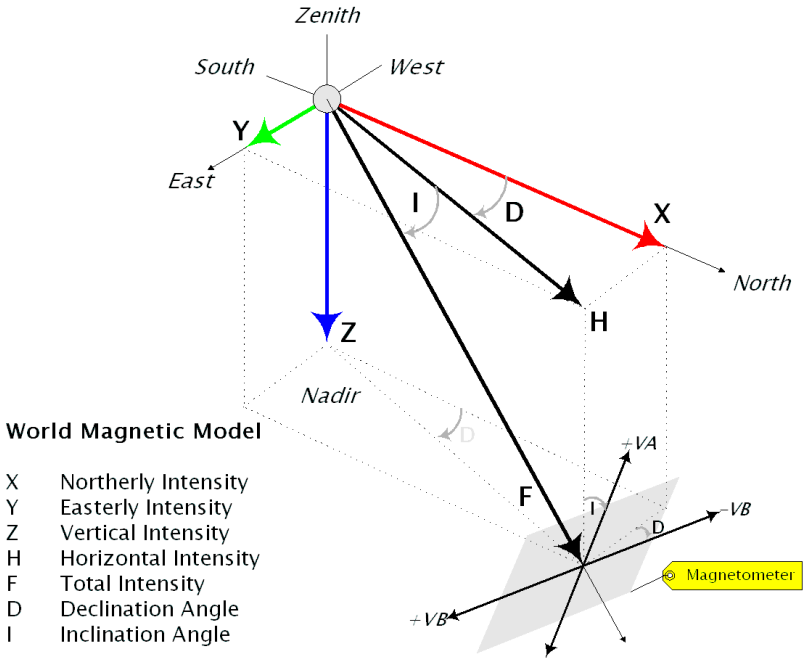

Figure Alignment of UKRAA Magnetometer with magnetic field[4]

The A axis responds to changes in the angle of Inclination I, and the B axis responds to changes in the angle of Declination D. It is important to remember that the Magnetometer is only sensitive to changes in the angle not the intensity of the field.

It is interesting to compare this with a three-axis fluxgate magnetometer which is often used by amateur observers to record the Earth's magnetic field. In these instruments the sensors are aligned North-South (X), East-West (Y) and vertically (Z) and respond to changes in the intensity of the magnetic field.

3 *The author*

4 *Extract from UKRAA Magnetometer User Manual*

5. British Geological Survey (BGS) Data

The BGS operates three magnetic observatories in the UK at Hartland (Devon), Eskdalemuir (Dumfries and Galloway) and Lerwick (Orkney) and posts real time observation online at https://geomag.bgs.ac.uk/data_service/space_weather/current_conditions.html

The results presented in this article rely on the data collected at the BGS Hartland magnetic observatory. In addition to the observational data there is considerable background information on geomagnetism which makes a useful reference guide.

The BGS website displays values for the horizontal component H, the vertical component Z and the declination angle D. I compare my observation (made in Kent) with the Hartland data and see a good correlation of the changes in the declination angle and my B axis results. For the B axis a positive change is due to a decrease in the angle of declination (D) and a negative change is due to an increase in the angle.

It was far less clear if there was any correlation between the H and Z values and my A axis results.

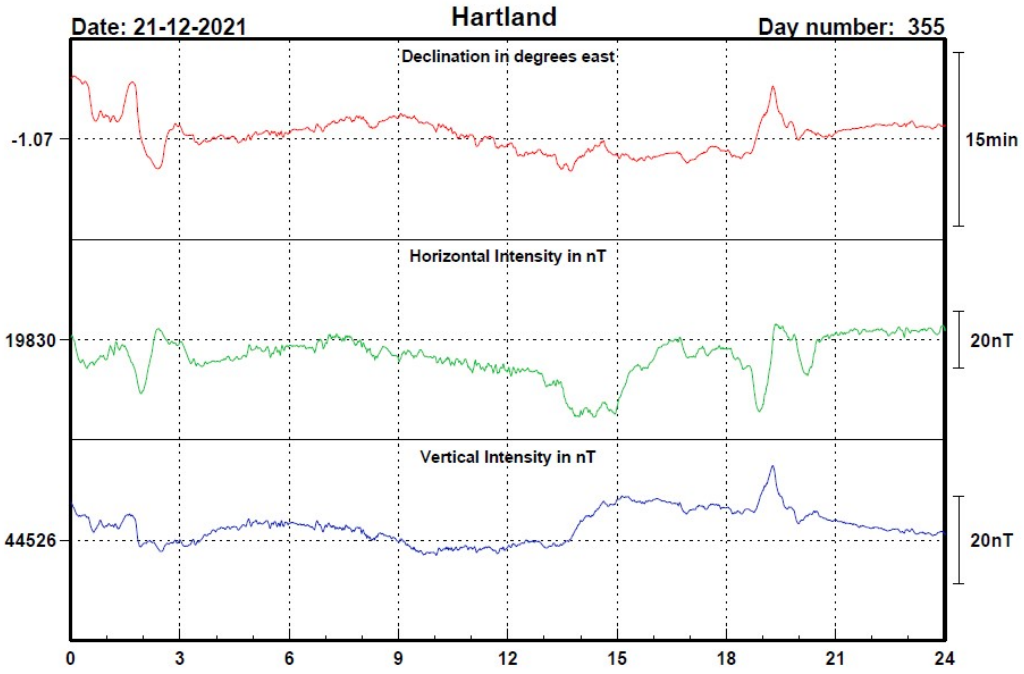

Figure BGS data for Hartland 21/12/2022[5]

5 *BGS Monthly Magnetic Bulletin Hartland Observatory December 2021. Reproduced with the permission of the British Geological Survey UKRI. All rights Reserved.*

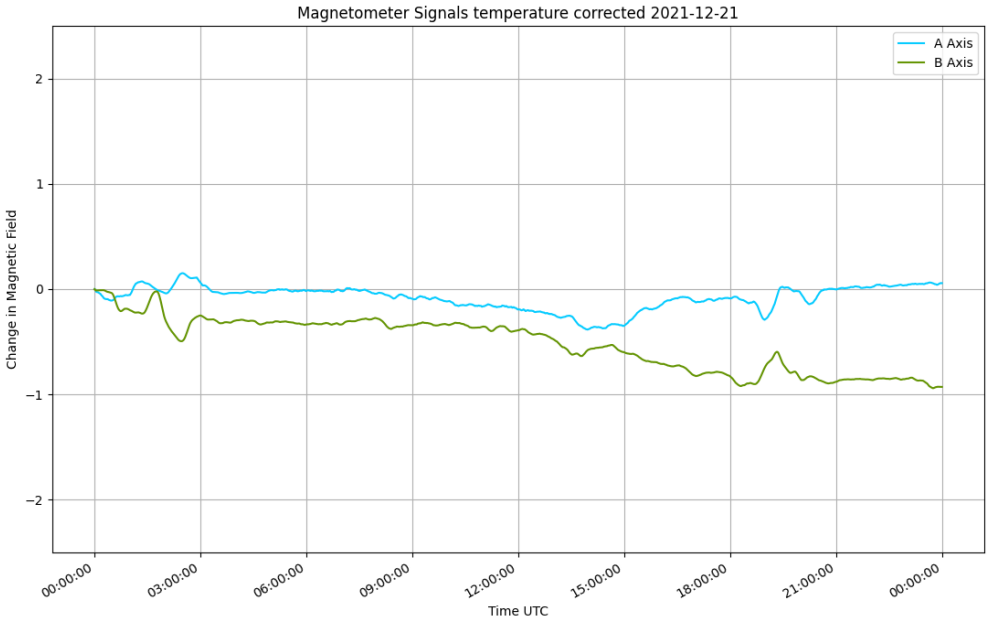

Figure Tonbridge data for 21/12/2021[6]

The H and Z components of the magnetic field recorded by BGS are absolute measurements of the strength of the field in those two directions. That means the value will vary due to changes in the intensity of the magnetic field and in its direction. Because the UKRAA Magnetometer is insensitive to changes in intensity of the magnetic field, this makes any direct comparison very difficult. BGS do not provide the actual measured values of H and Z on their website. Therefore it is not possible to calculate the angle of inclination (I) at any particular time from their data. If this calculation were possible BGS data could be compared directly with the UKRAA Magnetometer's A axis output.

6. Summary

The UKRAA Magnetometer records changes in the Earth's magnetic field and is sensitive to the angle of Inclination (I) and Declination (D). It does not respond to changes in the magnitude of the magnetic field.

The UKRAA Magnetometer and a 3-axis magnetometer each record different parameters of the World Magnetic Model. Both methods are effective at recording disturbances in the geomagnetic field produced by solar activity.

About the Author

I currently observe VLF signals and ionospheric disturbances and have added a magnetometer to observe the impact on the Earth's magnetic field of solar wind and coronal mass ejections. My next project is to improve my understanding the observations and share my data online.

Andrew Thomas is a Trustee of UKRAA. www.ukraa.com

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