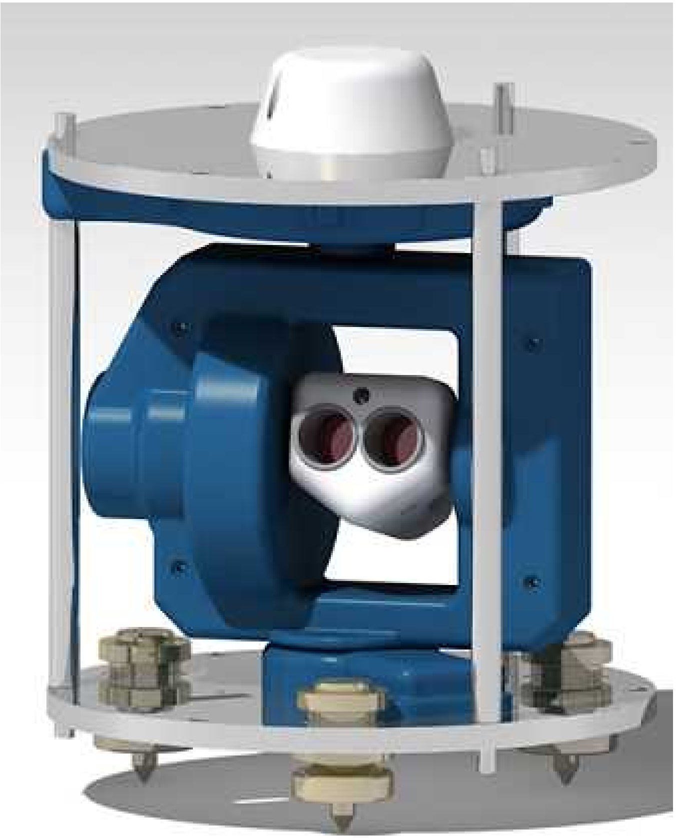
Measuring Earth's Magnetic Field Attitude:

AUTODIF MKII

Commercial Brochure



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Purpose of the AUTODIF

Everywhere on the planet Earth a magnetic field, roughly in the form of a North-South aligned dipole is present but is not perceptible to humans. These magnetic field lines circling the Earth on Figure 1 can be conveniently used for navigation on the surface of our planet by using a compass. The compass allows to display the direction of the magnetic field lines. Because the magnetic field lines are aligned in a North-South direction, the compass needle indicates a North direction.

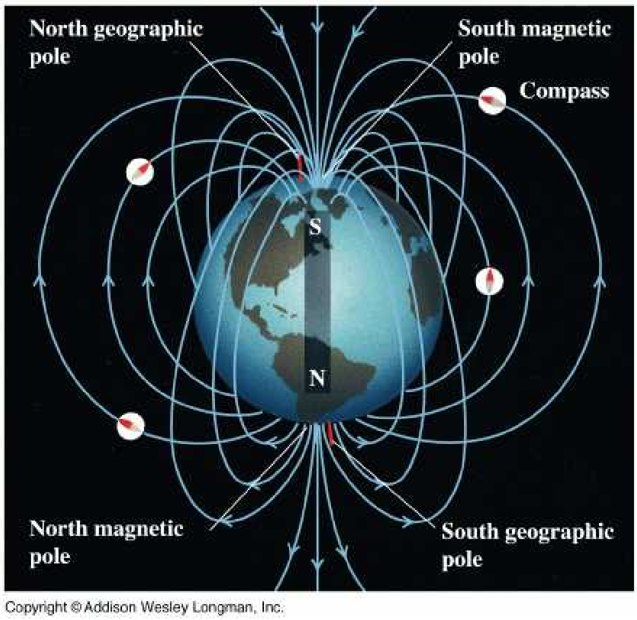

Figure 1. The Earth and its magnetic field.

A successful navigation by the compass supposes the knowledge of the exact layout of the magnetic field lines, differing slightly but significantly from a pure dipolar configuration and moreover affected by small secular changes and quicker space-weather influences.

The AUTODIF is designed to precisely measure the directions of these magnetic field lines with respect to the True north and the local Vertical. When enough of these measurements are available on the Earth, global maps like the IGRF can be produced, greatly helping in the accurate navigation with a compass; see for instance: http://www.geomag.bgs.ac.uk/research/modelling/IGRF.html

Once the AUTODIF has been stably installed in a magnetically clean place (usually a magnetic observatory), it will measure on a regular basis and unattended two angles giving the local field line attitude: the magnetic declination D and inclination I.

Until recently these attitude measurements (called absolute measurements) were carried out by the observer in charge with a DIflux theodolite[1], making unattended measurements impossible. The AUTODIF changes that as it is fully robotized and can measure autonomously.

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[1] Jankowski J. and Sucksdorff C. Guide for Magnetic Measurements and Observatory Practice, IAGA, ISBN: 0-9650686-2-5, Warszawa, 235pp, 1996.

Instrument description

The AUTODIF MKII is a non-magnetic robotized DIFlux theodolite for measuring the earth magnetic declination and inclination. The system is composed of 3 major parts (Figure 2):

1. A non-magnetic robotized AUTODIF theodolite able to orient a collinear single axis magnetic fluxgate sensor and laser beam towards any direction.

2. An electronic console sending and receiving electrical power and signals from/to the theodolite. It is connected by an 8m long cable to the theodolite

3. An acquisition system containing the software connected to the console through a USB (A-B type) connection, recording the measurements in files and transmitting data to the INTERNET.

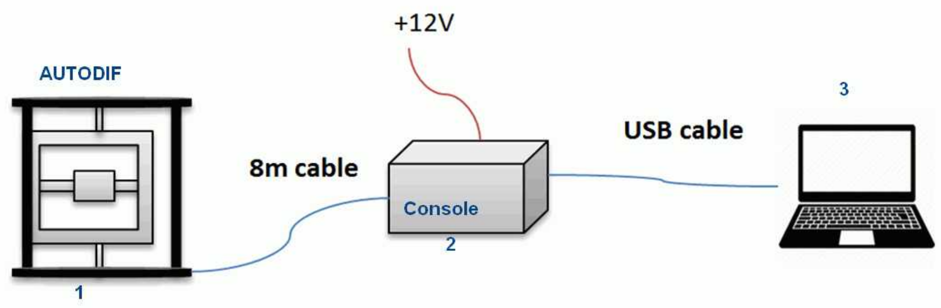


Figure 2. The AUTODIF hardware.

The AUTODIF theodolite structure is similar to conventional DIflux theodolites used in magnetic observatories. Two (2) orthogonal axes are aligned vertically and horizontally in a Cardan set-up. They allow a probe holder (Figure 3), containing a collinear fluxgate and a semiconductor red laser, to be oriented according to the measurement protocol in various directions. Electronic optical encoders monitor each axis in order to measure their angular rotations. The two rotary motions are created by means of non-magnetic piezoelectric motors. The motor action is transmitted by friction to ceramic rings on the axes. Therefore it is also possible to rotate manually around both axes, by overcoming the friction holding torque of the motors.

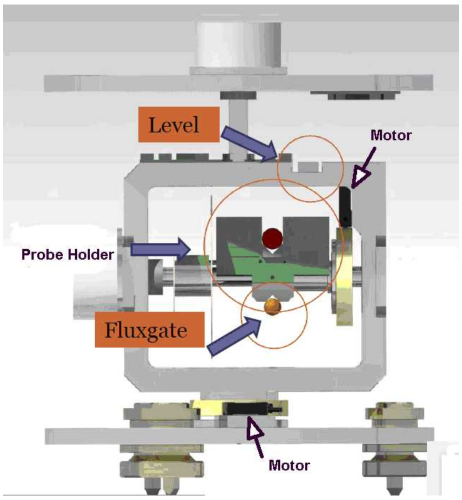
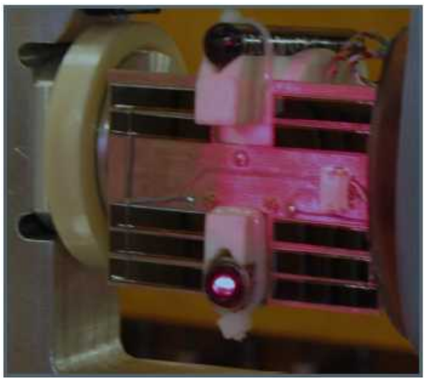


Figure 3. The AUTODIF sensor, showing the location of the different components

The reference to the local Vertical is obtained by a sensitive electrolytic level mounted on the alidade. During rotation around the vertical axis, the alidade mounted level allows any tilt to be monitored and to be possibly corrected by manual adjustment of the leveling screws. The level also allows correcting the index of the horizontal axis angular encoder.

The reference to True north in the horizontal plane is obtained by the conventional method used in most magnetic observatories. Therefore, a virtual line between the AUTODIF centre axis and a distant target is established. The azimuth of this line must be measured beforehand by separate geodetic techniques. In the AUTODIF, this virtual line is materialized by a laser beam reflected by a corner cube reflector. The emitting laser is surrounded by photocells. The laser is mounted on the probe holder collinearly with the fluxgate sensor (Figure 4). When the laser beam illuminates the corner cube, some light is reflected back to the laser and the photocells around it receive the returning beam. When the incident beam points the center of the corner cube, both photocells groups receive the same amount of returning light. The laser beam is then collinear with the virtual line joining the AUTODIF and the target, whose azimuth is known.



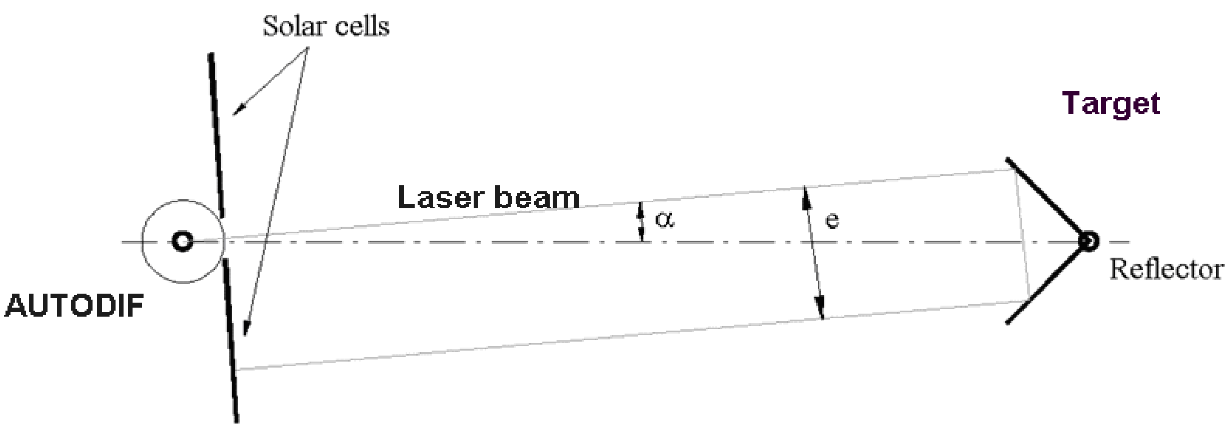


Figure 4. The AUTODIF laser beam orientation system. Upper left: the laser and photocells, Upper right: the cornercube reflector The distance between AUTODIF and Target should be between 50 and 120 m.

Instrument setup

INSTALLATION AND DEPLOYMENT

The instrument is usually installed in a magnetic observatory although outdoor installations have performed successfully for limited periods of time. It is necessary to provide good stability in tilt and orientation to the AUTODIF (better than 1 arcsecond). Ideally, a pillar should be dedicated in the absolute house or in another non-magnetic building (see Table 6). The corner-cube must be visible from the pillar. The laser can shoot through a window (refraction may have to be taken into account).

Installation on a tripod should be possible if enough stability can be achieved. Similarly a corner cube on a tripod can be deployed.

Even if it is possible to use a close by target, it is better to put it at least at 50m distance from the AutoDIF. We have successfully tested target distances up to 120m. The optical path should be horizontal within 10 degrees. The target azimuth must be determined beforehand by geodetic techniques.

The angular magnetic elements at the AUTODIF deployment site should be known within +/- 5 degrees in order to facilitate the first set-up.

SETTING UP

LOCAL PARAMETERS AND ENCODER REFERENCES

After entering the first requested parameters specific to the location in use (magnetic elements, target azimuth, observatory data) in the controlling computer GUI, initialization of the AUTODIF should be performed in order to reference the encoders on both axes.

LEVELLING

Then the instrument is manually leveled using the standard theodolite protocol. Information from the electronic level on the alidade is read from the GUI (Figure 5) and used during the process just as the bubble level is used on a conventional theodolite: orientation of the level in two orthogonal directions followed by levelleing and checks at 180 degrees.

TARGET POINTING

The set-up procedure then calls for indicating to the AUTODIF where to look for the corner cube target. Target pointing setup requires some experience and is first best done by the manufacturer. The easiest way is to do it by nighttime when the laser beam and its reflection are easily seen. Once the laser is pointing on the target corner cube and the photocells receive a reflected signal, the laser beam is within his pointing range. The reflected light can be maximized by fine motions of the probe holder.

The pointing range mainly depends on the target distance. Typically, a target 100m away provides a +/-0.01° pointing range. The target pointing set-up demands the record of both vertical and horizontal angle values as set-up parameters in the GUI for both sensor up and down. Any slow drift in the target reading will be accommodated over time by the AUTODIF by slightly modifying the set-up values. If, for some reason, the view to the target is obstructed, the magnetic measurements will proceed after the unsuccessful target pointing attempt.

DEFAULT MAGNETIC DIRECTIONS

It is then necessary to tell AUTODIF what are the approximate values (+/-5°) for the 4 magnetic meridian trace on the horizontal circle and the 4 inclination values in the magnetic meridian. Those values can be quickly found using manual rotations and reading the fluxgate values on the GUI: basically performing a DIflux protocol with basic precision of about 1°.

OPERATION

After setting up, a measurement sequence of the magnetic declination and inclination can be initiated. The automatic measurement sequence follows the classical DIflux protocol for eliminating all collimation and offset errors so as to obtain the "absolute" declination and inclination. The target direction and the levels are carefully checked during each measurement.

The operation can be watched and controlled onscreen by the graphical user interface (Figure 5). All instrumental parameters (fluxgate, level, photocell outputs as well as encoder readings and motor status) can be monitored in real time while the measurement is in progress.

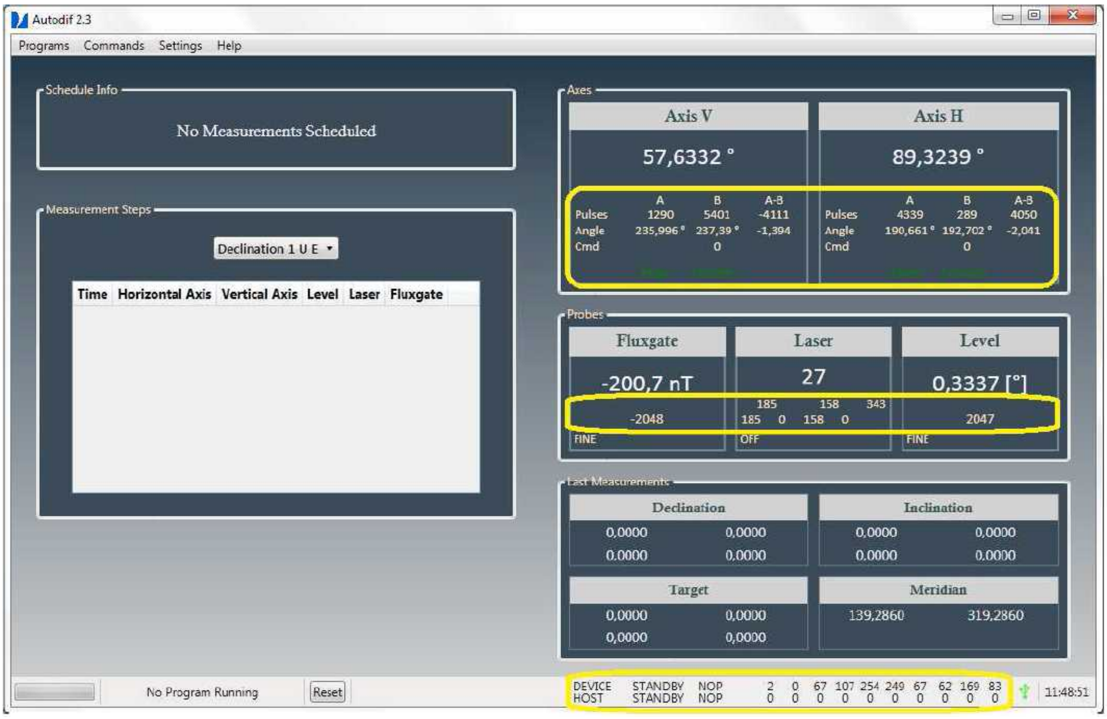


Figure 5. The graphical user interface allowing the monitoring and control of the AUTODIF operation and the parameters set-up

The measurement results may be stored in various supports and formats including an emulation of a manual DIflux measurement form.

A scheduler will allow the full measurement protocol to be carried out automatically at any repetition rate up to 4/hour.

The operation should go hand in hand with the observatory varriometer and proton magnetometer so as to determine variometric baselines. The high measurement rate allows the determination of varriometer baselines with unsurpassed time resolution.

AUTODIF accuracy and performance

MAIN SPECIFICATIONS AND CHARACTERISTICS

The AUTODIF has a basic accuracy of a few arcseconds for both the magnetic declination and inclination. However, the AUTODIF performance and overall accuracy depend on several ancillary sensor specifications and procedures:

1. Angular motion measurement accuracy
2. Amagnetism of the apparatus and environment (pillar, building,…)
3. Fluxgate noise level and drift
4. Accuracy in referencing to True North and the local vertical
5. Measurement protocol

The overall accuracy depends on the above points in a complicated way. In particular, the angular accuracy (see Table 1) depends on how circle graduation errors are averaged out by the measurement protocol.

Measurement of the overall accuracy is based on inter-comparisons with other absolute instruments and procedures like during the IAGA observatories workshops (Figure 6). Experience during those workshops show that the AUTODIF is at least as accurate as the best manual instruments. However, we cannot give a specific figure as it is difficult to have an agreement level better than 10 arcseconds between the different intercompared instruments.

In the tables below, specifications are given for the sensors in the AUTODIF.

Table 1. Rotational motion of horizontal or vertical axis

Angle reading resolution	0.36 arcseconds
Angle measurement absolute accuracy (single reading / ISO 17-123)	Better than 6 arcseconds
Motor positioning resolution	3.6 arcseconds
Vertical Index level compensation range (by software) = Max permissible levelling error	+/- 120 arcseconds

Table 2. Sensors

Fluxgate sensor resolution	0.1nT
Electrolytic level resolution	0.2 arcseconds
Target pointing resolution	Better than 1 arcsecond

Laser beam wavelength	650 nm (visible red)

Table 3. Measurement

Full DIflux-like measurement sequence duration	< 15 minutes
Programmable measurement rate	4 sequences/hour - 1 sequence/week9
Max distance console / PC	5m (USB norm) Possibility to use 100m USB extender
Recommended min distance AutoDIF / console	3m

Table 4. Physical

AUTODIF dimensions	230mm (external diameter) x 350mm (height)
AUTODIF weight (console – sensor)	5kg - 12 kg
Foot-screws configuration	120° on 190mm diameter circle
Console magnetic signature	<1nT at 1m
AUTODIF - console cable length	8m
Minimum cable (AutoDIF to console) bend radius	500mm
AUTODIF sensor temperature operating range	5-50°C (in cold areas a heating system is needed)

Table 5. Power

Console supply voltage	12 – 18 VDC
Console recommended power supply	DC 12V @ 2A
PC power supply (model fitPC)	AC 100-230V 50/60Hz 1.6A
Power consumption (idle mode) excluding PC	16W
Power consumption (motion mode) excluding PC	20W

Table 6. Recommended pillar layouts for sensor and target

Type	Non magnetic Indoor pillar with geodetic grade stability
Top surface	25x25cm² minimum
Foot-screws receptacles	V-groove crapaudines spread at 120° on 190mm diameter circle (orientation is specific to target direction)
Recommended pillar height	0.5m to 1.5m
Recommended AutoDIF/ target distance	50-120m (line of sight must be horizontal within 10°)
Target mounting support	Outdoor geodetic grade pillar with 5/8” screw (for the target-corner cube)

Internet availability: Internet availability is not required but recommended in order to benefit from free software update as well as remote control and assistance (troubleshooting and AutoDIF data control)

Figure 6. The AUTODIF in operation during the Observatories IAGA workshop in Hyderabad.