

ADAPTIVE AEROMAGNETIC REAL-TIME COMPENSATOR

**COMPACT, LOW-COST,
STRAP-DOWN PACKAGE**

**IDEAL FOR HELICOPTER, UAV
& SMALL FIXED-WING
AIRCRAFT INSTALLATIONS**

**MAGNETICS & GENERAL-
PURPOSE DATA ACQUISITION**



- *Magnetometer interface for up to 4 high-sensitivity sensors (Cs, He or K)*
- *Front-end sampling rates up to 1280 Hz*
- *Magnetometer processor: 0.32 pT resolution, < 0.1 pT system noise, ± 10 ppb temperature stability*
- *Real-time compensation: up to 4 total-field magnetometers, and true gradients*
- *Proven, extremely robust compensation algorithms (AADCII legacy)*
- *Adaptive signal processing techniques – improved compensation and simplified calibration procedures*
- *User may customize Front End processing to specific installation requirements*
- *Embedded GPS receiver option (typ. dual-frequency, L-band corrections)*
- *Data recording & output, up to 80 Hz: complete raw, pre-processed and compensated data sets*
- *Post-flight compensation & analysis functions*
- *Dynamic compensation of on-board electronic (OBE) systems*
- *Gating of magnetometer readings for concurrent use with EM systems*
- *Real-time graphical output and user interface on any external display*
- *Four analog inputs for radar/laser altimeter, barometric pressure sensor, etc.*
- *Data acquisition via Ethernet*
- *Full monitoring/control from any Windows device (via Ethernet, or remotely via internet)*
- *Features targeted to UAV applications*
- *State-of-the-art HW & FW architecture based on advanced 64/32-bit processors*
- *Real-time operating system (RTOS): QNX 6.5*
- *Compact and light: 5.25 x 8.5 x 12", 10 lb.*

The AARC510 Adaptive Aeromagnetic Real-Time Compensator is a member of RMS Instruments' family of advanced instruments for aeromagnetic compensation in geophysical and environmental survey applications. Powerful, versatile and rugged, yet compact and light, the AARC510 is ideally suited for "strap-down" installations onboard helicopters and small fixed-wing aircraft.

The AARC510 is based on the AARC500, which in the mid-2000's replaced RMS Instruments' AADCII as the *de facto* standard in aeromagnetic compensation in the geophysical exploration industry throughout the world. The result of many years of R&D on aeromagnetic compensation by RMS Instruments, and collaborations with the Flight Research Laboratory of the National Research Council of Canada, this technology offers the ultimate in compensation, delivering unparalleled performance, accuracy, consistency and reliability.

The system is built on the foundation of state-of-the art, very reliable hardware and firmware, and sophisticated and robust compensation algorithms that have been proven in a multitude of installations.

Aeromagnetic Compensation

The quality of the data collected in aeromagnetic surveys is largely dependent on the quality of compensation. Despite the outstanding sensitivity of modern magnetometers, in the absence of good compensation anomaly signals can be completely masked out by the interference of the nearby magnetics of the aircraft.

The aircraft's magnetic interference is related to its motions about its principal axes. A mathematical model may be built to accurately represent the aircraft's magnetic signature. Careful optimization and implementation of this model, within the framework of sophisticated hardware and firmware technologies, can lead to real-time compensation that effectively eliminates the aircraft's magnetic interference.

The RMS Instruments' AARC510 Adaptive Aeromagnetic Real-Time Compensator provides real-time compensation of local magnetic interference for inboard magnetometer systems in fixed wing aircraft and helicopters, to the point where the full resolution of modern high sensitivity magnetometers can be utilized. The compensation accounts for the effects of permanent and induced magnetism, eddy currents, and heading errors from the sensors.

The importance of real-time compensation

The magnetic signature of typical survey aircraft changes dynamically, even while in-flight. A simple toolbox or headphones misplaced in the cockpit, for example, will cause a significant DC-shift. Detecting subtle changes while monitoring uncompensated signals is practically impossible, as the disturbances introduced are "buried" under aircraft interference noise. State-of-the-art aeromagnetic surveying requires real-time monitoring of compensated data – problems are thus identified immediately and are promptly corrected. Relying solely on post-flight compensation is akin to "flying blind".

Calibration mode, model and solution

The AARC510 uses a 3-axis fluxgate magnetometer to monitor the aircraft's position and motion with respect

to the ambient magnetic field while flying a set of standard maneuvers of rolls, pitches and yaws in orthogonal headings. This *calibration* process, which typically takes 6-8 minutes, yields a (mathematical) *solution* that models the aircraft's magnetic signature. The solution is calculated instantly, upon termination of the calibration maneuvers. It is immediately available for use in compensated (i.e., survey) mode, or for further analysis and comparison with other solutions.

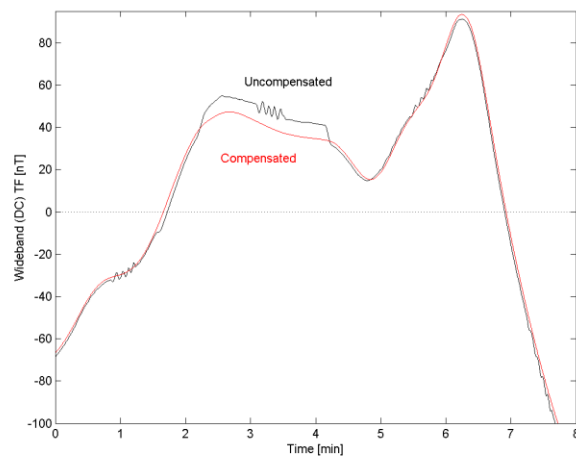
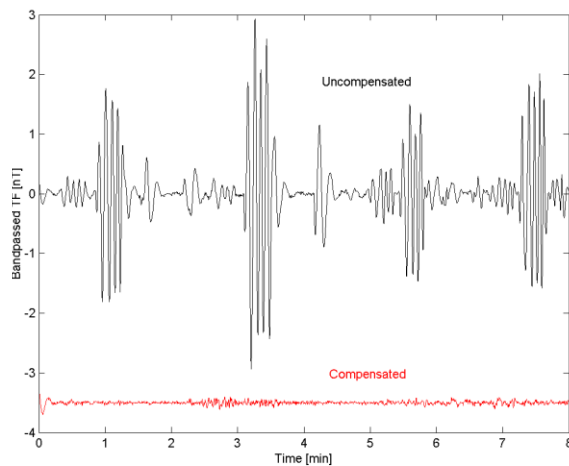
With the AARC510 there is no need for any post-flight software. The calibration is effective for the full 360° range of headings. At very low dip angles, *partial calibrations* for each active zone can be readily combined to produce a single robust solution for the full 360° range.

Compensation – total fields & gradients

In *compensation* mode up to 4 total-field (TF) high-sensitivity magnetometers, as well as associated gradients, are compensated in real-time using the last solution obtained (or any other solution previously archived). Compensated and uncompensated data, along with the 3-axis fluxgate magnetometer and other ancillary data, are monitored and recorded in real-time. Importantly, the system provides *true* gradient compensation: independent calibration solutions are calculated for the lateral, longitudinal and vertical gradients.

Adaptive compensation

The AARC510 incorporates adaptive signal processing techniques that allow the system to continuously "learn" from input signals, and adapt the solution coefficients for optimum compensation. The underlying recursive algorithm has significant computational advantages over the "conventional" alternative, and leads to improved band-passed and gradient compensation. Adaptive compensation substantially eases calibration procedures, and yields solutions that remain close to optimum as the aircraft's magnetic signature changes with time.



Left – Bandpassed uncompensated and compensated data for a full calibration flight (8 minutes). The uncompensated waveform clearly shows the aircraft interference on the four headings.

Performance indicators: $\sigma_{uncomp} = 0.5502$ nT, $\sigma_{comp} = 0.0282$ nT, IR = 19.5. (Waveforms are offset for clarity.)

Right – Wideband uncompensated and compensated waveforms. (Mean value subtracted for clarity.)

Dynamic compensation of OBE systems

The AARC510 incorporates new technology that allows real-time dynamic compensation of the effects of DC currents from on-board electronic (OBE) systems, such as avionics, hydraulics, control systems and other instrumentation. The compensation model is augmented by a suitable set of terms calculated by running a simple “calibration” procedure. OBE compensation simplifies operational requirements for operators during surveys, increases robustness and tolerance to electrical sources, and improves overall compensation performance. The technology works both for fixed- and variable-current devices, for as many as four independent OBE systems.

System Architecture

RMS Instruments' compensation technology is based on a flexible architecture with dual 64/32-bit processors. It includes state-of-the-art COTS (industrial-grade) electronics, and a proprietary magnetometer interface with excellent accuracy.

Front End sampling rates up to 1280 Hz and finely-tuned transfer functions deliver outstanding anti-aliasing characteristics, and may be customized by the user to the specific requirements of an installation. The highly stable and reliable time base and counter circuitry yield outstanding performance with negligible noise and temperature drift.

The main program and real-time operating system (RTOS) reside in solid-state memory. The RTOS is QNX 6.5 (or later), a deterministic and extremely reliable operating system tailored to mission-critical applications.

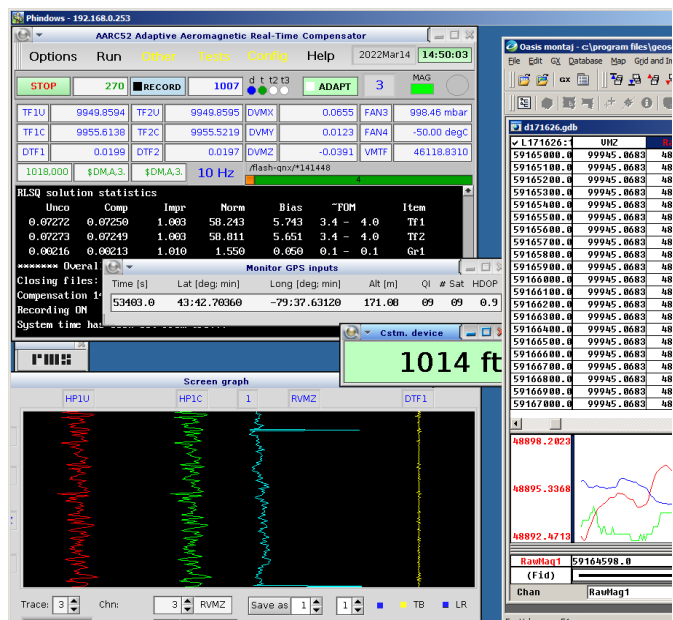
A three-axis fluxgate (vector) magnetometer is included with the system. Signals are processed using a high-resolution (16-bit) A/D converter.

Comprehensive statistical information is provided to assess the quality of compensation. The AARC510 will typically achieve *Improvement Ratios* (IRs) in the range of 10–20 for total fields in large and magnetically complex aircraft. For gradients, figures in the range of 20–100 are typical, with better performance possible when using adaptive compensation.

All magnetics (raw and compensated) and ancillary data may be recorded and monitored in real-time, at rates up to 80 Hz. Real-time data output via a serial (UART) port or Ethernet are also available. For concurrent use with EM systems a gating signal qualifies magnetometer readings.

All data are recorded in an embedded solid-state (Flash) drive (≥ 32 GB). Direct recording on an external Flash drive via USB is also available.

The intuitive graphical user interface is supported via any standard VGA display and USB mouse/keyboard, with additional options available for remote control.



Remote control from Windows

A remote connectivity tool for the AARC510 allows users full control and operation of the unit from a remote Windows-based system, across an IP network.

The user interface of the AARC510 is seamlessly replicated in the Windows-based computer. The mouse and keyboard attached to the computer have the same effect as if they were directly connected to the AARC510.

This technology facilitates integration of complex systems, with a single computer/laptop being used to control and operate the AARC510 and other instruments, while simultaneously running complementary software.

GPS receiver

The system is available with an embedded (typically dual-frequency) GPS receiver. All magnetics and ancillary data are referenced to GPS time and position. A variety of receivers are available to satisfy different requirements in accuracy. The AARC510 gives users direct access to two ports on the receiver. This provides, for example, the interface to a navigation system. The system can also be used with an external (user-supplied) receiver.

Post-flight compensation & analysis functions

Advanced embedded functions allow post-flight survey compensation, in the event a suitable calibration was not available at time of flight. This complements the fundamental real-time compensation function. Also included are functions for in-depth analysis of calibrations, and frequency-domain analysis.

General-purpose data acquisition

The AARC510 supports acquisition and recording of streaming data via Gigabit-Ethernet, with up to three independent logical connections. This allows interfacing to ancillary devices such as gamma-ray spectrometers, radar/laser altimeters, and barometric pressure sensors.

Four general-purpose high-resolution differential analog inputs are included. Two of them may optionally be assigned to embedded barometric pressure and temperature sensors.

The system includes flexible means for real-time monitoring of the data streams acquired via Ethernet, as well as the analog inputs.

ORDERING INFORMATION

- **AARC510-X: Adaptive Aeromagnetic Real-Time Compensator.**
Includes: Counter/processor for 'X' (2...4) magnetometer inputs; fluxgate magnetometer; QNX license; interface for external GPS receiver; mating connectors; user's guide (electronic); AFSC (firmware/support contract) for one year.
- **Performance Package: Selectable Front End (FE) sampling rates & transfer functions; advanced user-customizable FE processing; field-upgradable FE firmware; mag. gating for concurrent use with EM; post-flight compensation & analysis functions; FE analog inputs (including OBE compensation & embedded barometric-pressure & temperature sensors).**
- **RMS4880A Magnetometer Power/Decoupler Module: RMS4880A-1 (up to 4 inputs).**
- **Embedded GPS Receiver Option: Typically, Novatel dual-frequency OEM-7 series supporting L-band corrections.**
- **Phindows Software & License: Connectivity tool allows MS-Windows platforms to remotely control the system via a TCP/IP network.**

AARC510 SPECIFICATIONS

Magnetometer Inputs:

Up to 4 high-sensitivity magnetometers:

Cs: Typ. 70 kHz – 350 kHz

K-41, K-39: Typ. 140 kHz – 700 kHz

He: Typ. 560 kHz – 2.8 MHz

Magnetic Field Range:

Per the magnetometer's range; e.g.:^[1]

CS-3, CS-L, CS-VL: 15,000 – 105,000 nT

G-822A, G-823A: 20,000 – 100,000 nT

GSMP-30A: 20,000 – 100,000 nT

Gradiometer:

True gradient compensation – individual models/solutions for each of 3 gradients

Triaxial sensor geometry

Front End (FE):

Time base: > 100 MHz, OCXO

Resolution: 0.32 pT^[2]

System noise: $\sigma < 0.1$ pT^[3]

Temperature stability: $\approx \pm 10$ ppb^[4]

Sampling rate: 160, 640, 800 or 1280 Hz – user-selectable^[5]

Transfer function (bandwidth): 1.6 Hz, 3.25 Hz, 6.4 Hz, 9.8 Hz, 20 Hz, $0.16F_{SH}$, $0.13F_{SH}$ or Custom – user-select.^[5]

Compensation Performance:

Conventional (manned) fixed-wing, helicopter:

$\sigma \approx 20$ pT, full flight envelope, 0–1 Hz

IR, total fields (TFs): 10–20, typical

IR, gradients: 20–100, typical

Adaptive mode: Recursive approach with user-selectable gain; up to 2–5X further improvement (typical), band-passed TFs & gradients.

UAV: Consult RMS Instruments

Optional Filter (Host):

User-selectable, 0.4 – 3.0 Hz BW

Calibration Duration:

6–8 minutes, typical

Fluxgate (Vector) Magnetometer:

Included with the AARC510

3-axis fluxgate

Oversampling, 16-bit, self-calibrating ADC

OBE Compensation:^[5]

Dynamic compensation of up to 4 independent on-board elec. systems

Uses FE analog inputs

EM Gating:^[5]

For concurrent use with EM systems

LS-TTL input with pull-up

Data Output & Recording:

F_{SH} : 10, 20, 40, 80 Hz (GPS-PPS or internal synch.); external-trigger

Serial port: 115.2 kbps, ASCII/Binary

Ethernet: TCP/IP packets, ASCII/Binary

Recording media: embedded Flash SSD (≥ 32 GB), USB Flash disk

External display (VGA)

Event Inputs/GPS Synch.:

Three latched event inputs

LS-TTL levels, edge-sensitive

Event tags included with output data

Accuracy: per Front End sampling rate

Embedded Barometric Pressure & Temperature Sensors:^{[6][7]}

Differential inputs, 16-bit ADC

600 to 1100-mbar range; ± 5 mbar total accuracy

–50 to +100°C range; ± 1 °C abs. error

FE-Sampled Analog Inputs:^[5]

Four differential inputs

16-bit resolution, self-calibrating ADC

Input range: ± 5 Volts

Input resistance: 1 M Ω , typical

Data Acquisition via Ethernet:

10/100/1000Base-TX

Real-time, streaming data (TCP/IP)

Three independent logical connections

Sampling & recording: F_{SH} or submult.

Synch. to External Devices:

One pulse-train output

Rate: F_{SH}/x , with $1 \leq x \leq 255$

Low-going pulses, > 10- μ sec width

Remote Control:

Optional: From any Windows-based computer, via Ethernet – full replica of user I/F

Via serial (RS232) port – ASCII cmnds.

Indicators, General-Purpose I/O:

4 LEDs for mag. input status

2 LEDs for Front End status

Four USB 2.0

Data output (RS232, 9-pin D-sub)

Remote control (RS232, 9-pin D-sub)

10/100/1000Base-TX Ethernet (RJ45)

VGA video (15-pin D-sub)

GPS Receiver:

Standard: Interface to any GPS receiver with NMEA GGA output via RS232 (115.2 kbps, ≤ 10 Hz), PPS (LS-TTL, LV-TTL)

Optional: Embedded receiver – dual-frequency, GPS+GLONASS+QZSS, L1/L2, SBAS L1, PPP+Single-Point+DGPS-PNT, L-Band corrections (Other options: BeiDou, RTK posit., etc.)

Magnetics data tagged with GPS time, lat., long., altitude, and auxiliary data

Up to 10 Hz

Post-Flight Compensation:^[5]

Post-flight compensation & analysis functions for AARC510 binary d-files

Power:

+28VDC (± 6 VDC)

2.5A plus, for each mag. sensor, 1–1.5A^[6] during warm-up, 0.5A thereafter

Environmental:

Operating Temperature: 0 to +50°C

Storage Temperature: –20 to +55°C

Relative Humidity: 0 to 99%, non-condensing

Altitude: 0–6,000 m (0–20,000 ft)

Size (W x H x D): 216 x 133 x 305 mm, (8.5 x 5.25 x 12 in)

Weight: 4.5 Kg (10 lb)

Notes:

[1] Per manufacturer's specs. at print time: CS-3, CS-L, CS-VL (Scintrex), G-822A, G-823A (Geometrics), GSMP-30A (GEM Sys.).

[2] 1.6-Hz BW, 625-ms integ.

[3] Typical; 1.6-Hz BW, 625-ms integ., 10 Hz.

[4] Within operating temp. range. Over –20 to +70°C, $< \pm 35$ ppb.

[5] Requires Performance Package. Defaults: 640-Hz samp., 1.6-Hz BW.

[6] Dependent on type/model of magnetometer sensors.

[7] Uses 2 of the 4 FE analog inputs available.

Specifications per Host FW \geq RMS11031-03-H, FE FW \geq RMS1877-05-D, HW Rev. \geq 2.20, and subject to change without notice – Jan 2025.

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