

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 (single-, dual- or triple-frequency)
- Data recording & output, up to 80 Hz: complete raw, pre-processed and compensated data sets
- **NEW:** Post-flight compensation utilities
- **NEW:** Dynamic compensation of on-board electronic systems
- **NEW:** 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.

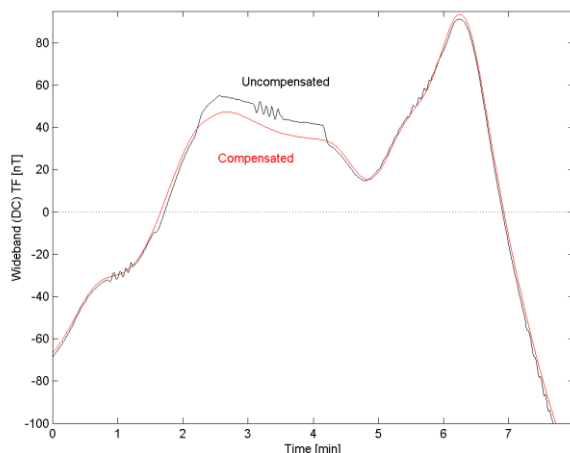
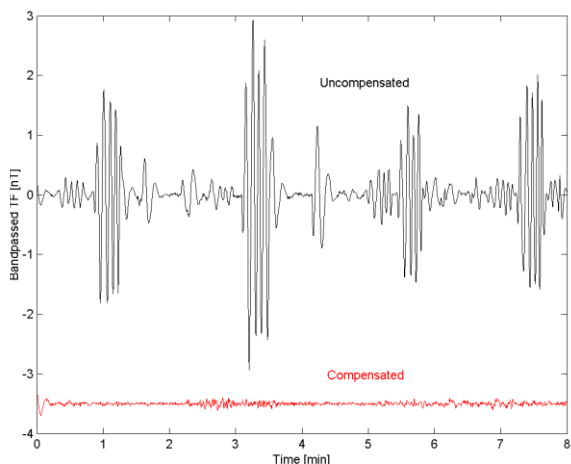
Compensation – total fields & gradients

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 vector 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 Description

The AARC510 is based on a flexible architecture with advanced 64/32-bit processors. It includes state-of-the-art COTS (industrial-grade) electronics, and a proprietary magnetometer interface.

Front End subsystem

The Front End in the system handles all magnetics data acquisition and processing, and provides accurate synchronization to GPS.

The magnetometer interface, most critical for high performance and data quality, uses the latest in analog and digital electronics to achieve excellent accuracy and synchronization for up to four high-sensitivity magnetometers. It uses a highly stable and reliable time base (OCXO). The proprietary counter circuitry delivers outstanding performance with negligible noise and temperature drift.

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

Front End sampling rates are user-selectable, up to 1280 Hz. Finely tuned, user-selectable transfer functions deliver outstanding anti-aliasing characteristics. The user may also customize Front End processing to the specific requirements of an installation.

For concurrent use with EM systems a gating signal qualifies magnetometer readings.

Host subsystem

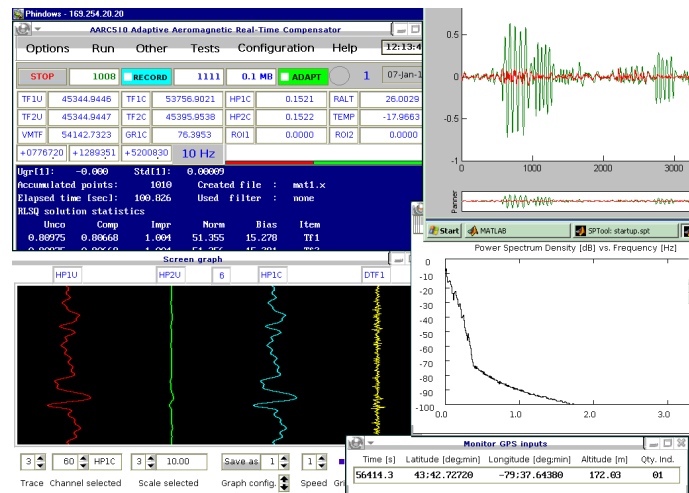
The application software and real-time operating system (RTOS) reside in (solid-state) Flash memory. The RTOS is QNX 6.5 (or later), a deterministic and extremely reliable operating system tailored to mission-critical applications, that guarantees compliance with the strict timing constraints of all critical tasks.

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. The Host software offers optional filtering with user-selectable bandwidths, and includes facilities for data analysis in the time and frequency domains.

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 port or Ethernet is also available.

Embedded solid-state Flash (≥ 8 GB) is typically used for data recording. Direct recording on a Flash disk connected to one of the USB ports is also available.

In addition to comprehensive data acquisition functionality, the host subsystem also provides extensive general-purpose I/O: output to any external display/monitor (via a standard VGA port), Ethernet, and multiple USB and UART interfaces. Configuration and control of the system are supported through an easy-to-use graphical user interface.



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 data acquisition via 1-Gbps Ethernet (TCP/IP packets), and offers the option of four differential, high-resolution analog inputs to complement magnetics data – e.g., radar/laser altimeter, barometric pressure sensor, etc.

ORDERING INFORMATION

- **AARC510-x:** Adaptive Aeromagnetic Real-Time Compensator. [x = # of magnetometer inputs; 2 ... 4]
Includes: – Vector (fluxgate) magnetometer.
– License/Key for QNX (RTOS) & Phindows (remote control from any Windows computer via IP network over Ethernet).
- **Advanced Functions:** Multiple FE smpl. rates & transf. funcs., raw FE logging, in-field FW updating, mag. gating for concurrent use with EM.
- **Post-Flight Compensation:** PFC and calibration analysis functions. Requires the Advanced Functions option.
- **RMS4880A Magnetometer Power/Decoupler Module:** RMS4880A-1 (up to 4 inputs).
- **GPS Receiver Option:** Internal (consult RMS Instruments for list of receivers available) or External.
- **Front-End-Sampled Analog Inputs:** 4 differential inps., 16-bit ADC. Required for OBE compensation.

AARC510 SPECIFICATIONS

Magnetometer Inputs:

Up to 4 high-sensitivity magnetometers;
any combination of:

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]

G-822A, G-823A: 20,000 – 100,000 nT

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

GSMP-30A: 20,000 – 100,000 nT

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, $0.16F_{SH}$
or Cstm. Transfer Funct.–user-select. [5]

Compensation Performance:

IR (total field): 10 – 20, typical

IR (gradient): 20 – 100, typical

(further improvement possible with adap-
tive compensation, 2X to 5X typical,
band-passed TF and gradient)

Compensation Accuracy:

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

Optional Filter (Host):

User-selectable, 0.4 – 3.0 Hz BW

Calibration Duration:

6 – 8 minutes, typical

Vector Magnetometer:

Included with the AARC510

3-axis fluxgate

Oversampling, 16-bit, self-calibrating ADC

OBE Compensation:

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

Requires FE-sampled Analog option

Data Output & Recording:

F_{SH} : 10, 20, 40, 80 [6] 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

memory (≥ 8 GB [6]), USB Flash disk

External display (analog RGB)

Event Inputs/GPS Synch.:

Four latched event inputs

LS-TTL levels, edge-sensitive

Event tags included with output data

Accuracy: per Front End sampling rate

Raw Data Logging: [5]

At Front End sampling rate

1-MB buffer

Ex.: 41666 records for 4 mag. inputs

FE-Sampled Analog – Optional:

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

TCP/IP

Sampling & recording: F_{SH} or submult.

Remote Control:

From any Windows-based computer, via
IP ntwk. over Ethernet – replica of
AARC510's user I/F on computer.

Via serial (RS232) port – ASCII cmdns.

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)

Analog RGB (15-pin D-sub)

GPS Receiver Option:

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

Up to 10 Hz

Internal (embedded) configuration –

Single-, dual- or triple-frequency receiv-
er from Novatel's OEMV-1, OEMV-2,
OEM6 or OEM7 series

External configuration –

Any GPS receiver with standard NMEA
GGA output via serial (RS232) port (up
to 10 Hz), and PPS trigger

Post-Flight Compens. – Optional:

Post-flight compensation & analysis func-
tions for AARC510 binary d-files

Power:

+28 VDC (± 6 VDC), 2.5 A

For each mag. input connected through
the RMS4880A Magnetometer Pow-
er/Decoupler Module: 0.5 A typical; up
to 1.0 A at turn-on [7]

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: G-
822A, G-823A (Geometrics), CS-3, CS-L,
CS-VL (Scintrex), 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] With AARC510 Advanced Functions Option.
Defaults: 640-Hz, 1.6-Hz BW.

[6] With HW Rev. ≥ 2.00 ; otherwise, up to 40
Hz, 2/4 GB.

[7] Per Geometrics G822A-type sensors. May
vary for other sensors.

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Specifications subject to change without notice
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