MEDICAL SHIELDING MAGNETIC ACTIVE COMPENSATION SYSTEM (MACS/D) FOR MRI

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- **High Performance, Reliable Adjustable Compensation Ratio (ACR) Architecture Applied to Environmental Shielding Designed Specifically for MRI Systems**
- **Three-axis High Power Compensation Corrects for Magnetic EMI in Extreme Environments**
- **Cancellation of Environmental Magnetic Interference Over Wide Frequency RangeThree-axis High Power Compensation Corrects for EMI in Extreme Environments**
- **Effective Protection Against Fluctuations in Magnetic Fields Caused by Subways, Elevators, Moving Vehicles, and Electrical Distribution Equipment**
- **Utilizes Axial Helmholtz Coil-Pair Design with Wide Range of Permissible Compensation Coil Geometries**
- **Probe Location External to MRI Isocenter Compensated Electronically via Included ACR Option**
- **Remote Access for All Monitor, Setup, Diagnostic and Parametric Adjustment Capabilities**
- **HTML Trace Page Permits Scrolling Display of Any Combination of 41 Selected Parameters**
- **Data Log Provides Detailed Output of System Status and Status History, as Required**
- **Secure VPN-protected Remote Access via Password Protected Hierarchal Levels; Critical Adjustments Access Limited to Highest Security Level**
- **Uniaxial Fixed Gradient Compensation (FGC) Capability Included; Uniaxial Adaptive Gradient Compensation Capability with Dual Probe Option (DPO)**

ETS-Lindgren's Digital MRI Series Magnetic Active Compensation System (MACS/D) provides cost effective, maintenance-free high performance attenuation of dynamic environmental magnetic fields for magnetic resonance imaging (MRI) and magnetic resonance spectroscopy (NMR/EPR) sites. The MACS/D system incorporates Active Compensation Ratio (ACR) technology (U.S. patent 9,692,391 B2), which enables higher compensation at the magnet's isocenter than other active compensation systems, providing effective attenuation factors in the isocenter of up to 350 versus 40 or less attainable by competing systems. Custom high-power coil drivers provide constant attenuation over a wide dynamic range >15 µTesla (150 mGauss) with standard coil sets in each of the three axes. Additionally, the MACS/D high efficiency, low dissipation coil driver amplifier insures long-term system reliability at sites experiencing frequent high-level interfering fields.

Signal processing within the MACS/D system is accomplished entirely in the digital domain via a high performance digital signal processing (DSP) engine. For ACR magnet isocenter attenuation enhancement, the digital processing algorithm applied in real time to the compensating signal accounts for the magnet's external to isocenter transfer characteristic.

For operator convenience, the MACS/D controller front panel screen provides three-axis scrolling displays of the residual magnetic fields, with text descriptions of instantaneous axial field values, the MACS/D system configuration, system state, time and date, and LAN IP. An embedded machine control computer provides full LAN-based capability for site setup and remote diagnostic viewing, with access to all data logging tools and files password protected. This includes a real-time HTMLbased monitoring page displaying up to 41 parameters. Additionally, password protected access to MACS/D standard and advanced operational parameters, DSP coefficients and system configuration is included in the standard software package. VPN client support is available for secure remote data logging and diagnostics via the designated "Capture" page, which acquires system parameters data over a configurable amount of recording time, sample rate, and file repetitions. Captured data files are stored locally and are downloadable as .csv files for viewing and analysis of system performance. The VPN support ensemble also includes provision for downloading of software upgrades.

ETS-Lindgren MACS/D systems for MRI and magnetic resonance spectroscopy employ traditional negative feedback, but with wideband, high resolution state of the art signal processing entirely in the digital domain, permitting incorporation of complex ACR algorithms to enhance performance. Gradient compensation provides additional attenuation in the B_0 axis by minimizing field gradients through the magnet volume. With the signal processing flexibility of the DSP based technology, the MACS/D provides superior compensation for higher order effects attributable to residual environmental field gradients.

MACS/D ACR technology, fast high-resolution conversion, and DSP architecture provides a high degree of software and firmware flexibility, also enabling remote MACS/D software upgrades, maximizing long-term utility.

From a reputation as industry leader with over 100 high performance MACS MRI installations worldwide, introduction of the MACS/D system advances ETS-Lindgren to a preeminent position of sourcing the world's premier active compensation system, specifically tailored for MRI sites.

Features

Autonomous Operation

Even absent remote monitoring or control, the MACS/D will resume normal operation in compensation mode with current parametric settings after an a.c. power interruption. At any start-up, the system performs comprehensive self-tests to confirm hardware and software integrity.

Secure Access

Remote Internet access via ETS-Lindgren managed VPN server provides maximum network security. The VPN client provides the ability to assign an access hierarchy and remotely and securely monitor, troubleshoot, diagnose, and update firmware/ software from any Internet access point.

Increased Power

The MACS/D system employs significantly more powerful and efficient coil drivers than previous MACS versions or any competing commercially available active compensation system, resulting in at least 100% or greater field compensation ability in each of the 3 axes. Maximum compensation is typically >15μT (150mG) for coils utilizing a single turn per axis of MACS/D standard gauge multiconductor cable installed in accordance with typical room geometry, up to 45μT (450 mG) peak, depending on coil cable type and room geometry. High efficiency switch mode amplifier architecture provides up to 500W output power per axis at 90% efficiency.

Comprehensive Monitoring

The front panel LCD displays real-time field level monitoring, system status, time and date, local IP address, system configuration, and warning/error messages. In the event of primary power interruption, the system self-restores and continues to provide field compensation with the same parameters, and with a notification presented in place of the normal readout display.

Straightforward Setup

Setup calibration requires only straightforward adjustment of the axial output gain settings, which are room geometry and probe location dependent, and a subsequent adjustment of the ACR level parameters, which are primarily dependent on the MRI magnet isocenter susceptibility to external magnetic fields. These setup parameter values are stored in nonvolatile memory and are reloaded at each power-up occurrence.

Fixed Gradient Compensation

Fixed Gradient Compensation (FGC) firmware is included for improved nulling of site Z-axis interfering fields that exhibit excessive gradients due to a proximate source or non-optimal coil geometry, building structure and or other similar causes. A fixed manual compensation adjustment for the FGC coefficient is included in the Z-axis parametric setups page.

Dual-Probe Option

A Dual-Probe Option (DPO) for selected-axis adaptive gradient compensation is included in the system firmware and can be implemented by the addition of a second probe to provide Z(B0)-axis adaptive-gradient capability. The Dual-Probe configuration of the MACS/D active compensation system implements a truly adaptive gradient operational mode in a single axis of the triaxial system. Its operation is essentially "automatic" in optimal compensation for one or more proximate interfering sources affecting the protected volume (PV).

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Technical Specifications

Electrical	
Input Voltage	95 to 125V or 210 to 240 AC (50/60Hz), 15A / 10A Maximum
Maximum Compensating Field	>15 µT (150 mG), Standard Cable Installation; >45 µT (450 mG) Augmented Cable Installation
Magnetic Field Sensor	1 mT/10 G Probe, Tri-axial, Plug-compatible with and Powered by MACS/D MRI-Configured Controller
Noise Floor	<0.3 nT (3.0 µG) rms, Determined Primarily by Sensor Noise Contribution
Baseline Acquisition Range	±0.9mT (±9.0 G) Maximum Environmental Static Field for Specified System Operation (Probe Dependent)
Operational Range	Baseline ±50 µT (0.5 G)
Front Panel Field Display Range	Autoscaled, up to 50 µT (0.5 G) (Averaged, Weighted Peak Absolute Magnitude)
Frequency Range	0.8 mHz to 500 Hz; ACR .01 to 10 Hz
Attenuation, MRI Isocenter	B_0 Axis: Factor of 100 (40 dB) Minimum, 200 (46 dB) Typical, 350 (51 dB) with Magnet-specific ACR Coefficients
Remote Monitoring	X, Y, Z Axial Fields (Absolute Magnitude) Residual Main Probe X, Y, Z Axial Fields Residual Aux (Optional Probe) X, Y, Z Axial Fields PEM (Parameter Extraction Module) X, Y, Z Coil Currents Drive Signal to Coil Driver Amplifier (CDA) X, Y, Z CDA CURRENT (a.c. Mains Input Current) Utility I/O Channel Values
Physical	
Dimensions	53.3 cm x 22.9 cm x 43.2 cm (21 in x 9 in x 17 in)
Weight	27.3 kg (60 lb)

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