MR QA/QC for MRgRT

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Department of Radiology
July 13, 2015

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Creating a cancer-free world. One person, one discovery at a time.




Quality Assurance and Control

"Quality begins with proper equipment selection"

W.R. Hendee The Selection and Performance of Radiologic Equipment, Baltimore, MD: Williams and Wilkins, 1985, p. 460.

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- Consult with Diagnostic Radiologist and Physicist
- Work collaboratively and develop synergies

Agenda

MR Siting Considerations

Imaging Quality Control

MR Simulation Specific QC

Agenda

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MR Simulation Specific QC

Siting Considerations

New Comprehensive Cancer Center

- December 2014 Opening
- 275 private in-patient beds
- Radiation Oncology located on 2nd floor
- 7 LINACS with OBI and CBCT
- CT Simulator
- PET/CT Simulator
- Brachytherapy Suite
- MR Simulator

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Siting Considerations

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Siting Considerations

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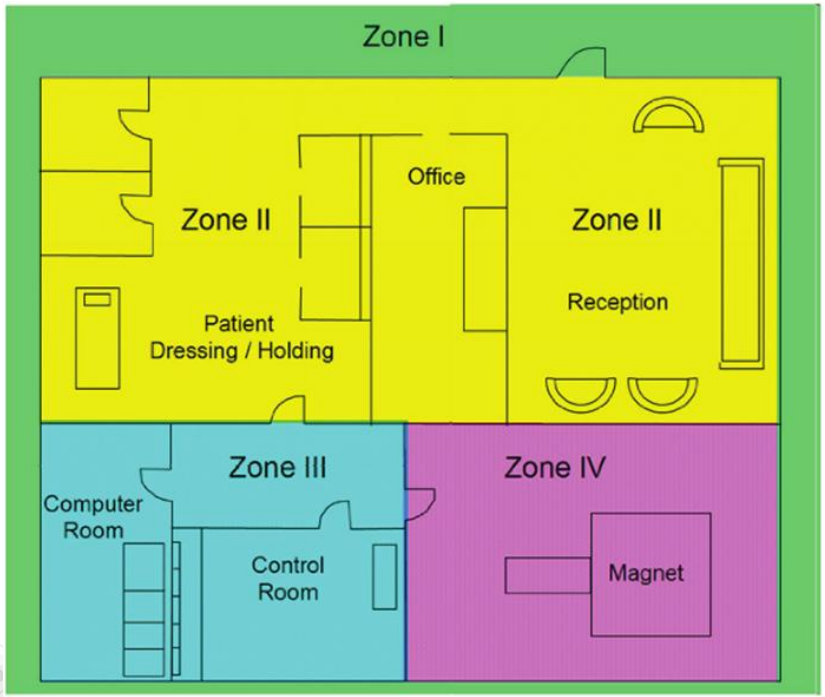
MRI Zones

Zone 1: free accessible
Zone 2: interface
Zone 3: restricted area
Zone 4: MR magnet room

MR Personnel
Non-MR personnel: patients, visitors, staff
Level 1: passed minimal safety and education training, Zone 3-4
Level 2: extensively trained, gatekeeper of Zone 4



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Siting Requirements – Interfere with Magnet

Source of Interference	1.5T X/Y and Z Axis	3.0T X/Y and Z axis
Steel reinforcement	4’-2”	4’-2”
Water cooling unit, chiller	13’-1”	13’-1”
Transport devices up to 440 lbs	17’-5” / 21’-40”	19’-8” / 22’-11”
Vehicles up to 2,000 lbs	18’-5” / 24’-8”	21’-3” / 26”-2”
Elevators, trucks up to 10,000 lbs	20’-5” / 29’-7”	22’-11” / 31’-2”
AC transformers less than 100 KVA	39’-5” / 26’-2”	39’-4” / 26’-2”
AC cables, motors less than 100 AMPS	9’-10” / 6’-6”	9’-10” / 6’-6”

Note: Example specifications applicable to Siemens Skyra (3T) and Aera (1.5T), Siemens Healthcare, Erlangen, Germany

Siting Considerations (Magnetic Fringe Fields) – Interfere with Object

Devices	Field Strength	1.5T X/Y and Z axis	3.0T X/Y and Z axis
Small motors, watches, cameras, credit card	3.0 mT	6’-1” / 9’-2”	6’-11” / 10’-6”
Computers, magnetic disk, processors	1.0 mT	7”-3” / 11’-6”	7’-7” / 13’-2”
Cardiac pacemakers, x-ray tubes, insulin pumps	0.5 mT	8’-3” / 13’-2”	8’-7” / 15’-2”
Color monitors, CT scanner	0.15 mT	9’-9” / 16’-1”	11’-2” / 20’-1”
LINAC	0.1 mT	10”-4” / 17’-1’	12’-6” / 22’-4”
X-ray image intensifier, gamma camera, PET/cyclotron	0.05 mT	13’-1” / 22’-3”	16’1” / 26’-11”

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MR Artifact

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MR Artifact

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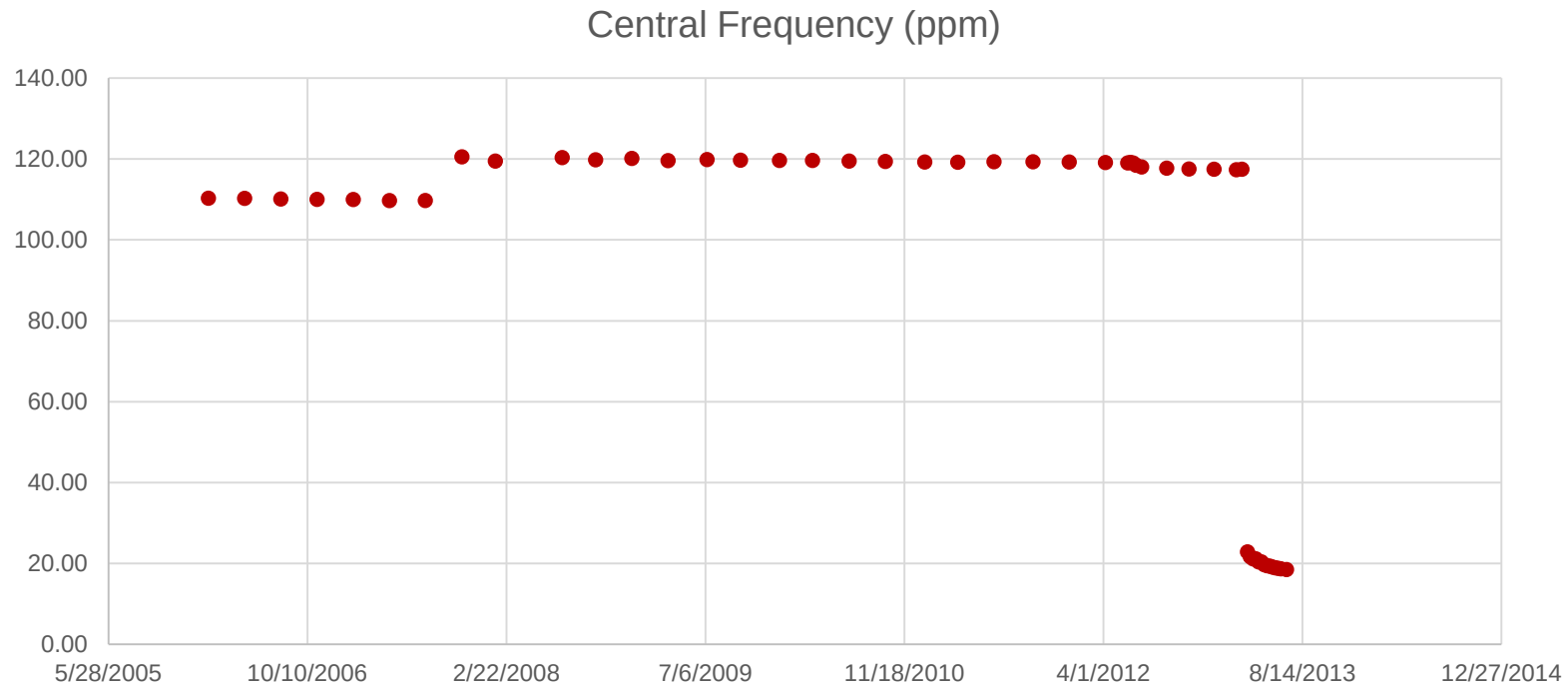
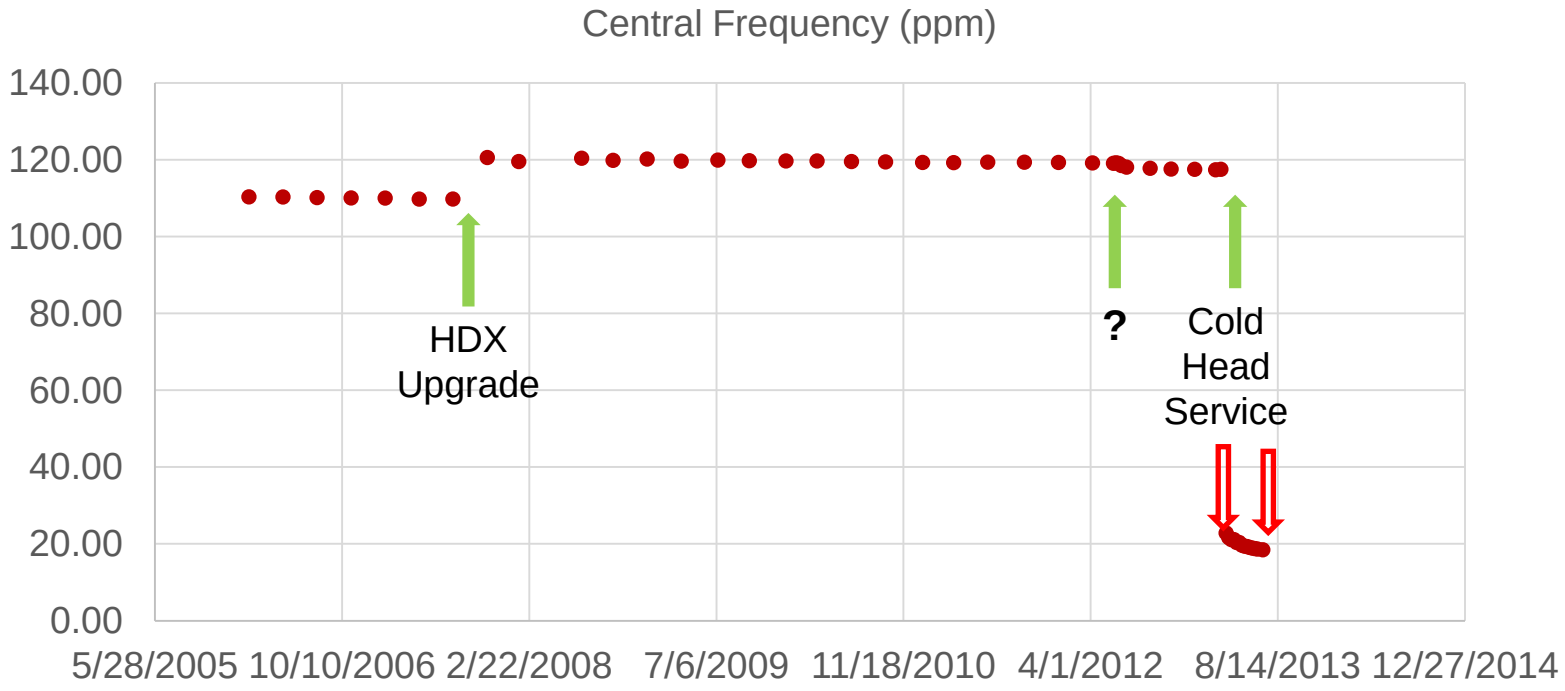
QC Example - CF Change Over Time



QC Example - CF Change Over Time



Agenda

MR Siting Considerations

Imaging Quality Control

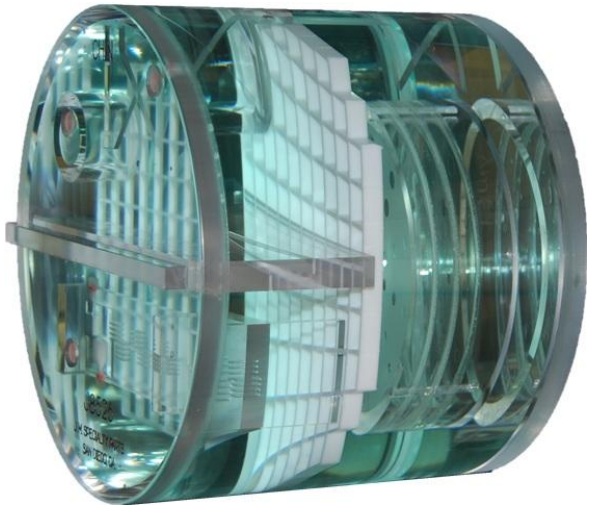
MR Simulation Specific QC

Updates and Changes to ACR MRI QC Manual

- Interslice RF interference removed
- Magnetic homogeneity and percent image uniformity procedure changes
  - ≥87.5% for systems up to 1.5T
  - ≥82% for 3T systems
- Signal ghosting added
  - ≤2.5%
- Low-contrast detection
  - 9 rows total for systems up to 1.5T
  - 37 rows for 3T systems
- Assessment of MR safety program

ACR MRI Phantom

- Filled with nickel chloride and sodium chloride solution (10 mM $NiCl_2$ and 75 mM NaCl)
- Length 148 mm
- Diameter 190 mm
- J.M. Specialty Parts Inc



ACR MRI Phantom

- Must be capable of providing tests ***substantially equivalent*** to the ACR phantoms and after they have been approved by a QMP or MR scientist.

QMP Responsibilities

- **Commission testing**

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QMP Responsibilities

- Commission testing
- **Annual testing**
  - **ACR, 12 months not to exceed 14 months**
  - **JC, 12 months not to exceed 13 months**
- **Repeat appropriate testing after major repair or upgrade**

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QMP Responsibilities

- Commission testing
- Annual testing
  - ACR, 12 months not to exceed 14 months
  - JC, 12 months not to exceed 13 months
- Repeat appropriate testing after major repair or upgrade
- **Establish Quality Control program**
  - **Baseline measurements and action limits**
  - **Establishment of new baseline values if needed after major repair**
- **Review QC records at least annually**

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QMP Responsibilities

- Commission testing
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- Review QC records at least annually
- **Assessment of MR safety program**

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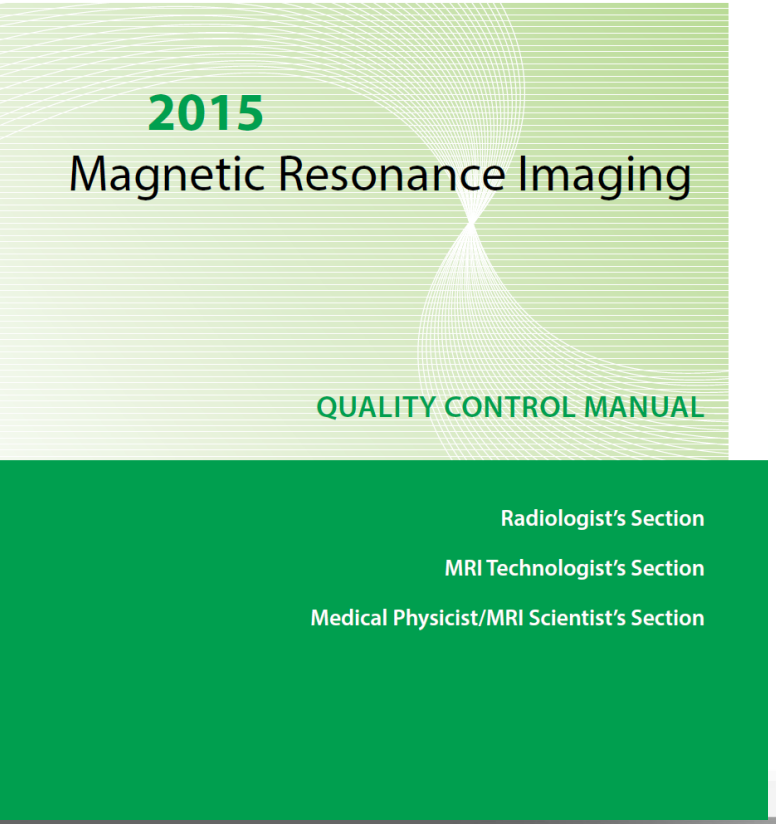

QMP Annual Tests

- Setup and table position accuracy
- Center frequency
- Transmitter gain or attenuation
- Geometric accuracy
- High-contrast spatial resolution
- Low-contrast detectability
- Artifact evaluation
- Film printer QC (if applicable)
- Visual checklist
- Magnetic field homogeneity
- Slice position and thickness accuracy
- Performance testing for coils used clinically
  - SNR
  - Percent image uniformity
  - Percent signal ghosting
- Soft-copy (monitor) QC

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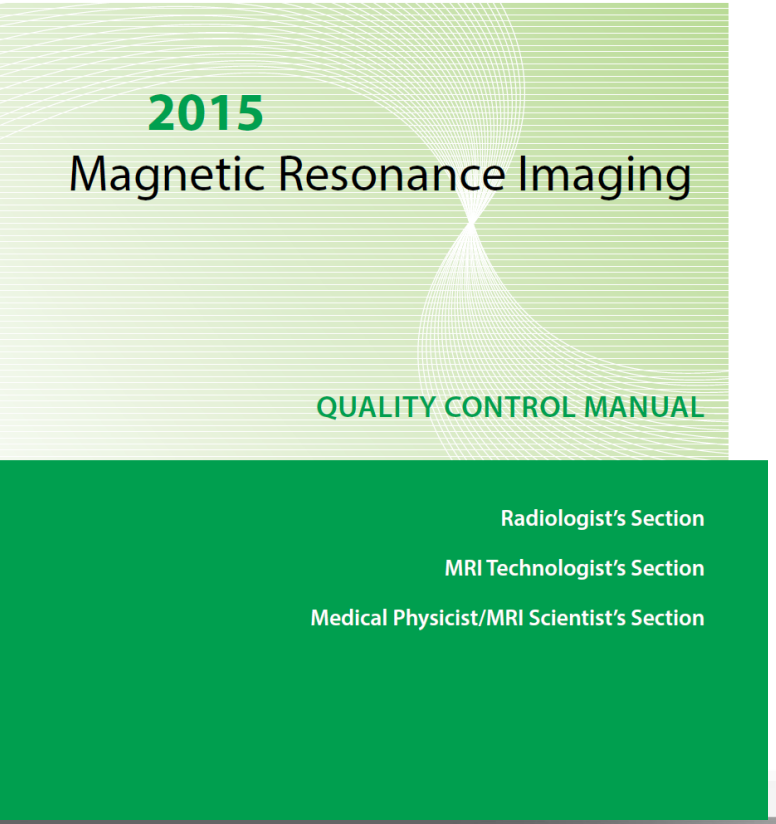

MRI QC Technologist's Responsibilities

- Setup and table position accuracy
- Center frequency
- Transmitter gain or attenuation
- Geometric accuracy measurements
- High-contrast spatial resolution
- Low-contrast detectability
- Artifact evaluation
- Film printer QC (if applicable)
- Visual checklist

All Performed Weekly

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Agenda

MR Siting Considerations

Imaging Quality Control

MR Simulation Specific QC

MR Simulation Specific Tests

Daily

- **Gantry lasers with center of image plane**

MR Simulation Specific Tests

Daily

- Gantry lasers with center of image plane

Weekly

- **Gantry lasers with respect to imaging plane**
- **Lateral wall lasers with respect to gantry lasers and scan plane**
- **Wall lasers with respect to the imaging plane**
- **Ceiling laser with respect to the imaging plane**
- **Orientation of MR tabletop with respect to imaging plane**
- **Table vertical and longitudinal motion**
  - **RT tolerance is typically ±1mm while most manufacturer's specify ±2mm**
- **Table indexing and position**
- **Scan localization**

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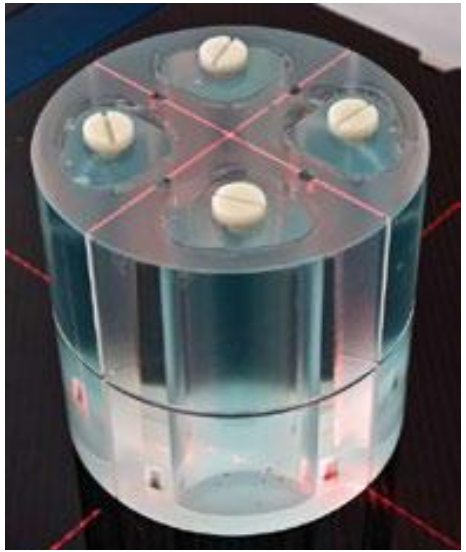
MR Simulator Acceptance Testing Results



A5. LAP Laser

Geometry

LAP Laser to MR Laser:	310	*mm*
LAP Laser to MR Isocenter:	1132	*mm*

Calibration

Calibration Accuracy	± 4	*mm*

Pulse Sequence (High FA)

SPGR, FA 20°, 340mm FOV, 256x256, 5mm slice, 1 slice, 11 slices, TR/TE = 31/MIN ms, NEX 4, BW 250 kHz, Auto Shim.

Image Quality

Laser	SNR	Ghosting Ratio
ON	174.6	0.03%
OFF	258.9	0.01%

Any Noticeable Imaging Artifact?	No
If yes, Type of Artifact:	N/A

Comment: The vendor LAP laser calibration phantom is not available. Calibration was done with Vitamin E capsules with ~9 mm diameter.

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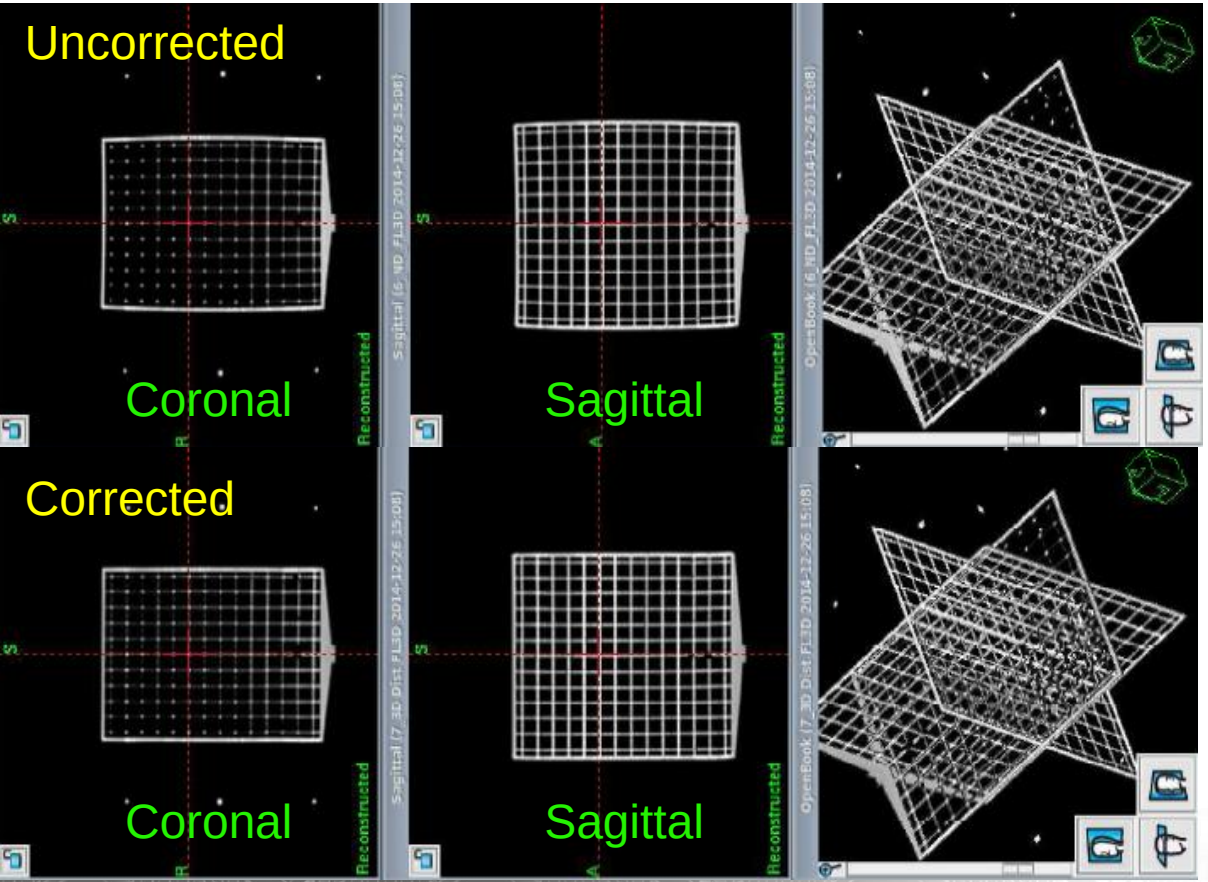
MR Distortion Analysis

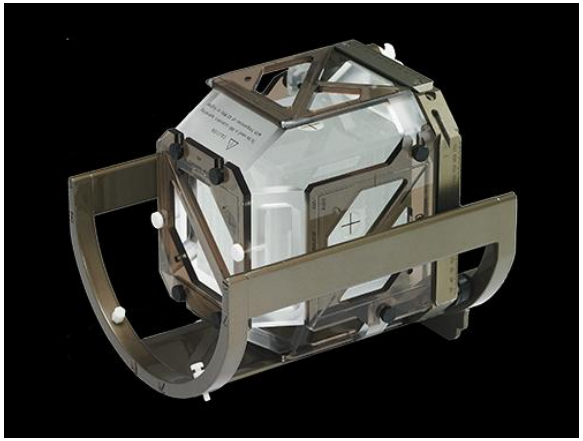
- Commercially available head phantom (body phantom prototype)
- Spatial resolution of 0.1 mm

<u>Acquisition Technique</u>

- 3D OEM gradient distortion correction is turned ON
- 3D T1 weighted sequence with 1 mm^3 isotropic voxels (GE-FLASH, Philips-Fast Field Echo, Siemens-VIBE)
  - 2 NEX
  - TE ~ 4 ms
  - TR ~ 9 ms
  - Flip angle ~ 10^o
  - Pixel BW ~ 120 Hz
  - Percent sampling 100%
  - Percent phase FOV 100%

MR Head Distortion Phantom Testing





- Dimension 14x13x11 cm^3
- Spatial resolution 0.1 mm

Images courtesy of Lanchun Lu, PhD

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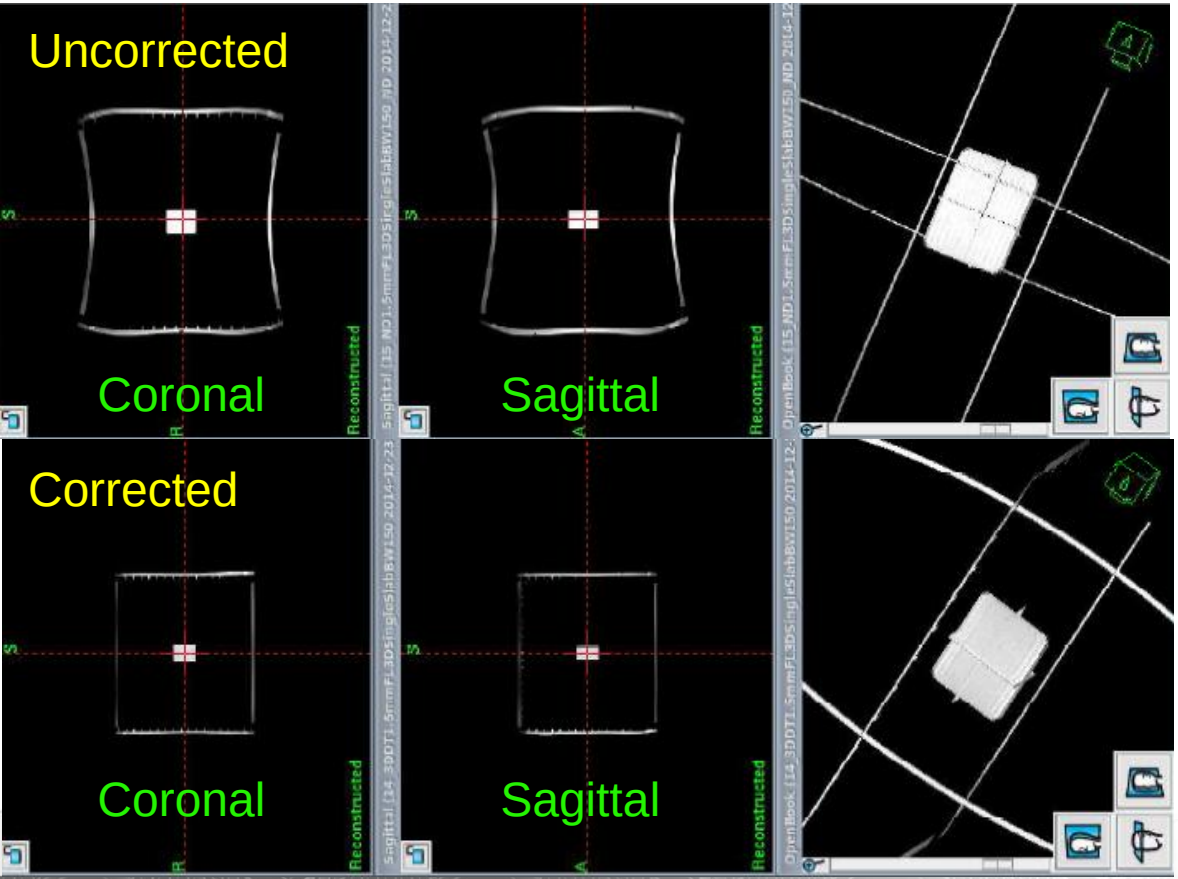
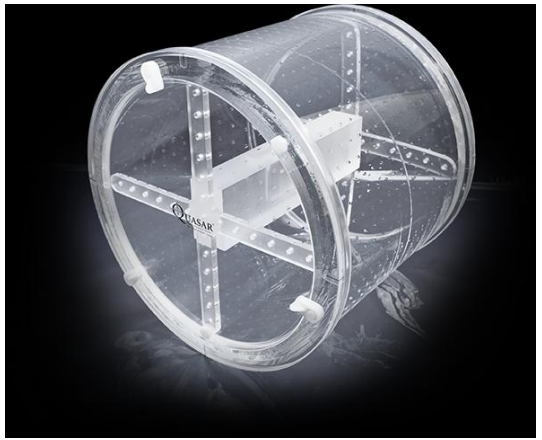
MR Body Distortion Phantom Testing





- 37 cm diameter
- 32 cm length
- 1562 mineral oil points
- Spatial resolution <1 mm^3 isotropic voxel

Images courtesy of Lanchun Lu, PhD

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Future Considerations

- New phantom design with improved tolerances
- Deformable co-registration
- Multi-modal fusion and co-registration

SAMS Question

Which of the following items is least likely to impact the performance of the MR system?

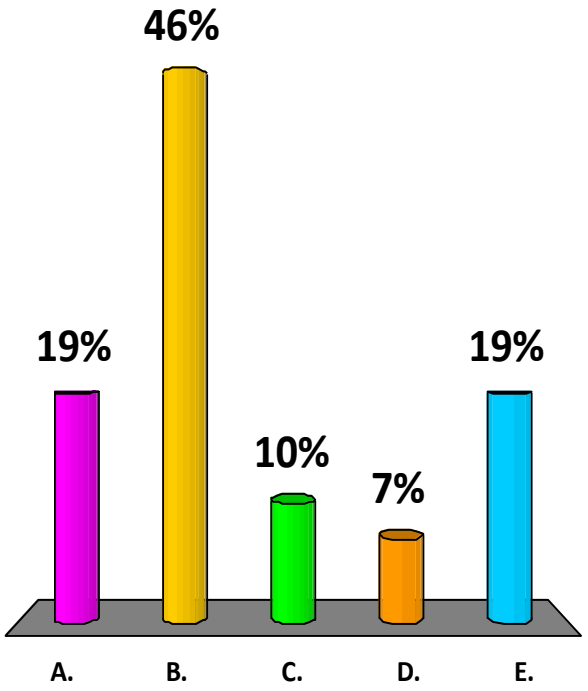
A. C-arm in an adjacent room

B. External lasers

C. Forklift operated in area behind the MR

D. Power injector

E. Patient monitoring device within the MR room



SAMS Question

Which of the following items is least likely to impact the performance of the MR system?

ANSWER: A C-arm in an adjacent room

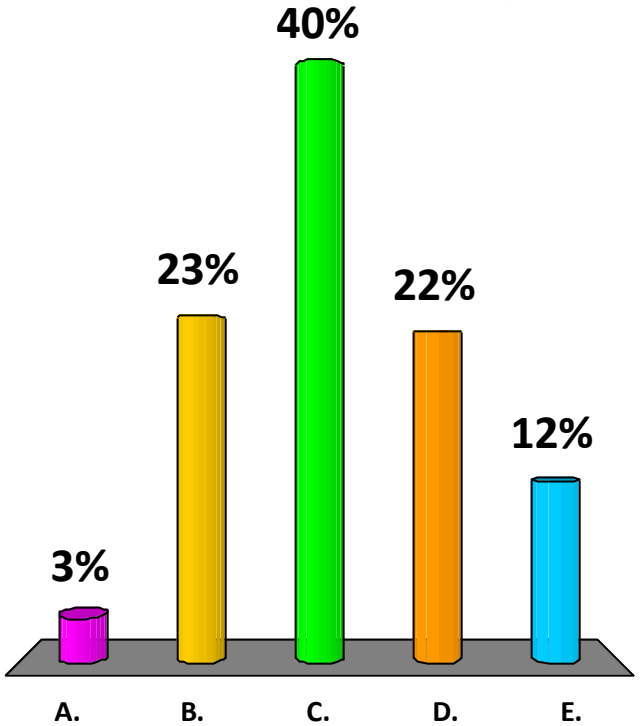
The performance of the c-arm could be impacted by the MRI but the distance of the c-arm would be too great to cause any interference with the MR system

Reference: All OEM specification cut sheets. Example, https://ftp.siemensmedical.com/pp-cutsheets/mr/skyra/Cutsheet-10024.pdf

SAMS Question

Based on the current technologies available for evaluation and equipment performance, what is the achievable MR laser accuracy?

A. 4.0 mm
B. 3.0 mm
C. 2.0 mm
D. 1.0 mm
E. <1.0 mm



SAMS Question

Based on the current technologies available for evaluation and equipment performance, what is the achievable MR laser accuracy?

Answer: C 2.0 mm

The manufacturer tolerance is 2.0 mm accuracy.

Reference: OEM equipment manuals, ECRI, MD Buyline

Additional References

- ACR website (www.acr.org)
  - MRI Accreditation Program Requirements
  - Breast MRI Accreditation Program Requirements
  - Phantom Test Guidance for the ACR MRI Accreditation Program
- ACR-AAPM Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment
- AAPM Report No 100: Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities
- Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. *Journal of Magnetic Resonance Imaging.* 2013; 37(3): 501-530.
- Gilk T, Kanal E. Interrelating sentinel event alert #38 with the ACR guidance document on MR safe practices: 2013. An MRI accreditation safety review tool. *Journal of Magnetic Resonance Imaging.* 2013; 37(3):531-543.