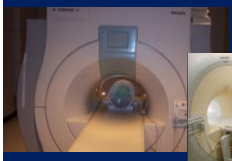
The Revised ACR MRI Quality Control Manual: Status Report



General Purpose: Whole Body

Dedicated : Breast

Extremity

Ron Price
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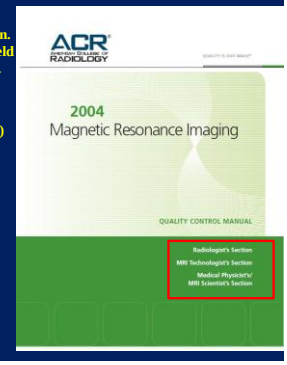
Overview: ACR MRI QC Manual 2014

- **Relatively minor changes from the 2004 version. Changes primarily for clarification. Added alternative methods for SNR and field homogeneity with emphasis on MRI safety.**
- **Updated version to be released in 2014 (Electronic with FAQs and annual updates)**
- **Radiologist's Section (Requirements and role in a QA program)**
- **Technologist's Section (Recommended daily /weekly QC tests)**
- **Medical Physicist / MRI Scientist's Section (QC program/Annual performance tests)**



However, accreditation requirements have changed significantly since 2004.

Specifically, due to the changing requirements of both the Centers for Medicare and Medicaid Services (CMS) and the Joint Commission (JC)

CMS requires that all facilities providing Advanced Diagnostic Imaging* services that are billed under Part B of the Medicare Physician Fee Schedule must be accredited by one of the CMS approved accreditation organizations by January 1, 2012:

American College of Radiology (ACR)
Intersocietal Accreditation Commission (IAC)
Joint Commission (JC)

**MRI, CT and Nuclear Medicine/PET*

The Joint Commission

Proposed Standards Changes for Diagnostic Imaging Services

Hospital Accreditation Program 8/8/2013

For hospitals that provide magnetic resonance imaging (MRI) services: At least annually, a medical physicist or MRI scientist conducts a performance evaluation of all MRI imaging equipment. The evaluation results, along with recommendations for correcting any problems identified, are documented.

- Image uniformity
- Slice thickness accuracy
- Slice position accuracy
- High-contrast resolution
- Low-contrast resolution (or CNR)
- Geometric or distance accuracy
- Magnetic field homogeneity
- Artifact evaluation

MRI Safety:

- **The hospital must manage safety risks in the MRI environment.**
- **MRI staff must participate in education and training on safe practices in the MRI environment**

Joint Commission Guidelines

Restrict access to all MRI sites by implementing the four zone concept as defined in the ACR Guidance Document for Safe MR Practices: 2013*. The four zone concept provides for progressive restrictions in access to the MRI scanner:

Zone I: General public
Zone II: Unscreened MRI patients
Zone III: Screened MRI patients and personnel
Zone IV: Screened MRI patients under constant direct supervision of trained MR personnel

* *Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practice: 2013. J Magn Reson Imaging. 2013;37(3):501-530.*

The Centers for Medicare and Medicaid Services (CMS) now require that all MRI facilities who bill under Part B Medicare to:

1. Meet all ACR performance guidelines
2. Operate at a field-strength ≥ 1T
3. Be accredited by ACR, JC or ICAMRL
4. Offer biopsy services
5. Provide both head and body scans

10

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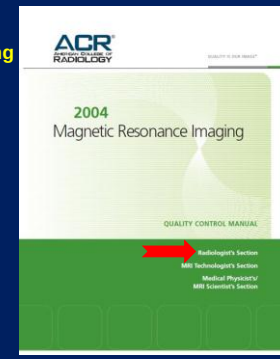
Reference: Centers for Medicare and Medicaid Services website http://www.cms.gov/Medicare/Provider-Enrollment-and-Certification/MedicareProviderSupEnroll/AdvancedDiagnosticImagingAccreditation.html

The Supervising Radiologist has overall responsibility for the site's accreditation program.

Responsibilities include:

- Assurance of staff training
- QC Program Review
- Medical Physicist assignment
- Annual Testing Review
- Safety Program Review
- Maintenance of Records and Documentation

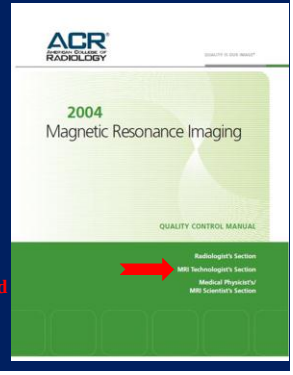


MR Technologist's Section

Technologist is responsible for weekly/daily QC tests:

1. Center frequency
2. Table positioning
3. Setup and scanning
4. Geometric accuracy
5. High-contrast resolution
6. Low contrast resolution
7. Artifact analysis
8. Laser camera QC (if applicable)
9. Visual checklist
10. *Ensure Universal-Standard Precautions for infection control are followed

* New in 2014 manual



Technologist's Section

Table 1. MINIMUM FREQUENCIES OF PERFORMING TECHNOLOGIST'S QC TESTS

Procedure	Minimum Frequency	Approx. Time (min)
Center Frequency	Weekly	1
Table Positioning	Weekly	3
Set up & Scanning	Weekly	7*
Geometric Accuracy	Weekly	2*
High Contrast Resolution	Weekly	1
Low Contrast Resolution	Weekly	2
Artifact Analysis	Weekly	1
Film Quality Control	Weekly	10
Visual Checklist	Weekly	5

*Some measurements can be performed simultaneously.

17 Minutes

Weekly Visual Inspection

- Check patient table, patient communication, patient "panic button", table movement and alignment and all light indicators
- Check RF room integrity (doors contacts and windows)
- Check emergency cart, safety lights, signage, equipment for MR compatibility and all patient monitors
- Check all RF coils for damage and cable integrity

Summary: Technologist's QC

- Technologist must perform QC tests at least weekly and record the results in the QC logbook
- If any test result exceeds the appropriate action limit (established by Medical Physicist/MR Scientist), the test should be repeated. If the result still fails to meet the action limits, the service engineer and/or medical physicist should be notified.
- Action limits are generally based on multiple measurements over extended time periods
- 2014 Manual included details on the use of both the ACR Large Phantom as well as the ACR Small Phantom

The ACR MRI accreditation program requires the technologist's weekly QA to include an assessment of:

1. Slice thickness accuracy
2. Magnetic field uniformity
3. Slice cross-talk interference
4. Geometric accuracy
5. Slice position accuracy

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The ACR MRI accreditation program requires the technologist's weekly QA to include an assessment of:

1. *Slice thickness accuracy*
2. *Magnetic field uniformity*
3. *Slice cross-talk interference*
4. *Geometric accuracy*
5. *Slice position accuracy*

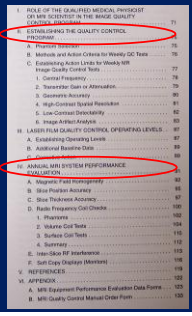
Reference: ACR website www.acr.org
ACR MRI Quality Control Manual 2004
Technologist's Sectioin II. A. page 25

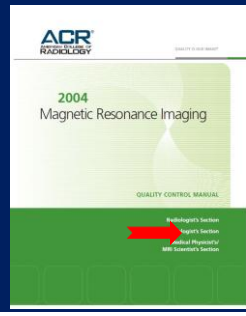
Medical Physicist's/MRI Scientist's Section

Medical Physicist is responsible for establishing the system QC Program and for Annual performance testing.

1.

2.





Establishing Action Limits for Technologist's QC

Specific action limits are the responsibility of the medical physicist but must be at least as restrictive as the ACR recommended guidelines.

How to start?

1. **Service engineer should run all vendor tests to assure system is performing to vendor specifications**
2. **Establish baseline during acceptance testing (AAPM Report 100)**
3. **Collect "weekly" QC data for at least 10 days**
   - **Central frequency**
   - **Transmitter gain / attenuation**
   - **Geometric accuracy**
   - **High contrast resolution**
   - **Low contrast resolution**
4. **Record as "Baseline" in Technologist's QC notebook**

QC Phantom Selection

The selection of the phantom used for routine QC is the responsibility of the medical physicist. The phantom should be capable of providing assessment of the JC/ACR/IAC required parameters and will typically dependent upon the type of scanner:

- **Whole body scanners – Large Phantom**
- **Extremity (Breast) scanners – Small Phantom**

ACR Large Phantom: 190 mm

ACR Small Phantom: 100 mm

Acceptance Testing: Image Performance

(Similar accreditation annual performance tests.)

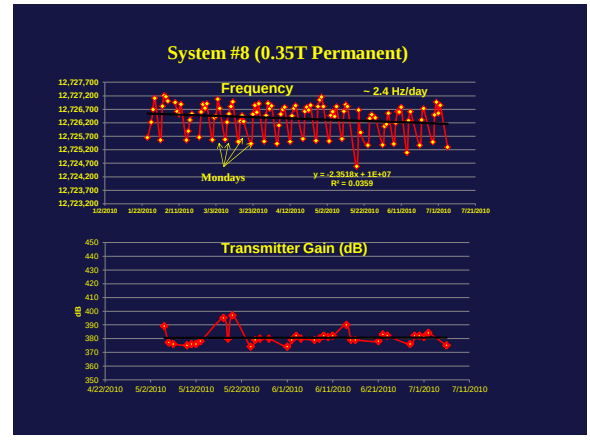
1. ***Static Magnetic Field: Uniformity and Drift***
2. ***RF System***
3. ***Gradient System***
4. ***System measurements***
   - *Slice thickness and position accuracy*
   - *Signal-to-Noise Ratio (SNR)*
   - *Percent Image Uniformity (PIU)*
   - *Percent Signal Ghosting (PSG)*
   - *High-contrast spatial resolution*
   - *Low-contrast detectability*

5. ***Advanced MR System Tests***
   - *Ultrafast (EPI) Tests (N/2 ghosting and spatial distortion)*
   - *Spectroscopy Tests (VOI position accuracy and spectral quality)*

Establishing Action Limits

General approach: Determine mean and standard deviation (SD). May need to use ± 2SD depending upon the system.

1. Central frequency expressed in ppm (typically ± 1.5 ppm)
   (1.5 ppm @ 1.5T ~ 96 Hz or determined from statistical analysis)
2. Transmitter Gain or Attenuation (expressed in dB)
3. Geometric Accuracy (± 2 mm)
4. High-Contrast Resolution (at least 1mm)
5. Low-Contrast Detectability (± 1 or 2 SD)
6. Artifacts (any artifacts should be noted and image saved)



DATA FORM FOR DAILY MRI EQUIPMENT QUALITY CONTROL

MR Facility Name: VCH
MR Scanner Identifier: 3T Philips
Month: August
Year: 2013
Reviewed By: A. B. Physicist
Date: 9/24/2013

1 Date of Test	2 fbn cb PF monitor, door contacts, table movement, alignment lights, cables, UPS	3 Helium Level	4 CF (Hz)	5 RF Drive Scale	Phantom Distances (mm) Sag Loc Length	Axial Slice #5 Diameters		Slice 1 HR Holes #		Slice # 8 No. of LCD Spokes	Artifacts Slice # 1 - any other obvious clips	Signal	Noise (SD)	SNR	Test By
					6	7	8	9	10	11	12		13	13	13
					H/F (148)	A/P (190)	R/L (190)	UL	LR						
Action Limits →	OK		± 100 Hz per day		± 2 mm	± 2 mm	± 2 mm	≤ 1.0	≤ 1.0	For Slice 8 ≥ 5/16 Visible	None			SNR>SNR ref/2	
8/6	OK	67	127,746,935	0.45	148	190	190	1.0	1.0	9	0	1295.6	6.63	275.5	KH
8/7	OK	66	127,746,919	0.45	148	190	190	1.1	1.1	10	0	1903.5	13.13	204.4	JM
8/8	OK	66	127,746,939	0.47	148	190	190	1.0	1.0	9	0	1861.1	8.23	284.6	JP
8/9	OK	66	127,746,900	0.46	148	190	190	1.1	1.1	10	0	1908.2	9.77	275.4	JM
8/10	OK	67	127,746,877	0.45	148	190	190	1.0	1.0	10	0	1881.7	10.22	259.6	ZR
8/11	OK	66	127,746,790	0.46	148	190	190	1.1	1.1	10	0	1903.1	13.11	204.7	JM
8/12	OK	67	127,746,796	0.46	148	190	190	1.0	1.0	10	0	1903.8	10.76	249.5	JM
8/13	OK	67	127,746,786	0.45	147	190	190	1.1	1.1	10	0	1897.4	10.04	266.5	JM
8/14	OK	67	127,746,723	0.53	148	190	190	1.1	1.0	10	0	1896.2	9.36	285.7	JM
8/15	OK	67	127,746,809	0.44	148	190	190	1.0	1.0	10	0	1618.9	9.49	240.5	JB
8/16	OK	66	127,746,822	0.46	148	190	190	1.1	1.1	10	0	1906.7	9.93	270.7	JM
8/17	OK	67	127,746,819	0.45	148	190	190	1.1	1.1	10	0	1870.5	10.45	252.4	KH
8/18	OK	67	127,746,808	0.46	148	190	190	1.0	1.0	10	0	1903.9	10.68	251.4	JM
8/19	OK	66	127,746,801	0.46	148	190	190	1.1	1.1	10	0	1913.9	10.38	260.0	JM
8/20	OK	67	127,746,782	0.46	148	190	190	1.1	1.1	10	0	1905.7	9.22	291.4	JM
8/21	OK	67	127,746,772	0.46	148	190	190	1.0	1.1	10		1908.7	10.19	264.1	JM
8/22	OK	66	127,746,724	0.46	148	190	190	1.1	1.1	10	0	1905.9	9.44	284.7	JM
8/23	OK	67	127,746,735	0.46	148	190	190	1.0	1.0	10	0	1899.6	10.46	256.1	JM
8/24	OK	67	127,746,707	0.45	148	190	190	1.0	1.0	9	0	1852.3	9.66	270.4	KH
8/25	OK	67	127,746,696	0.46	148	190	190	1.0	1.1	10	0	1896.7	9.8	272.9	JM
8/26	OK	67	127,746,701	0.46	148	190	190	1.0	1.0	10	0	1897.1	9.31	287.3	JM
8/27	OK	67	127,746,686	0.46	148	190	190	1.1	1.1	10	0	1900.3	10.79	248.3	JM
8/28	OK	67	127,746,625	0.46	148	190	190	1.0	1.1	10	0	1916	10.73	251.8	JM
8/31	OK	66	127,746,568	0.46	148	190	190	1.0	1	9	0	1853.8	9.27	282.0	KH

Annual Performance Tests

(*Red* indicate new 2014 requirements.)

		Technologist QC (Weekly)	Medical Physicist/MR Scientist (Annually)
1	Table Positioning, Setup and Scanning	X	X
2	Center (Central) Frequency	X	X
3	Transmitter Gain or Attenuation	X	X
4	*Geometric Accuracy*	X	X
5	*High-Contrast Spatial Resolution*	X	X
6	*Low-Contrast Detectability*	X	X
7	Artifact Evaluation	X	X
8	Hardcopy (Film) QC (if applicable)	X	X
9	Visual Checklist	X	X
10	*Percent Signal Ghosting (PSG)*		X
11	*Image Intensity Uniformity (PIU)*		X
12	*Magnetic Field Homogeneity*		X
13	*Slice Position Accuracy*		X
14	*Slice Thickness Accuracy*		X
15	Radiofrequency Coil Checks (SNR and PIU if volume coil)		X
16	Soft Copy (Monitor) QC		X
17	MR Safety Program Assessment		X

As part of annual testing, physicist must repeat and evaluation weekly Tech QC measurements as well as the sequences required for accreditation submission.
Note: Interslice RF cross-talk test has been eliminated.

Annual System Performance Evaluation

1. Repeat and Verify Weekly QC Measurements

- Setup and positioning accuracy (mechanical inspection)
- Central frequency.
- Transmitter gain or attenunation (head coil RF calibration)
- Geometric accuracy (gradient calibration)
- High contrast spatial resolution
- Low contrast detectability
- Image artifact assessment
- Hard copy (film) QC
- Soft copy (Monitor) QC
- Visual checklist

2. Perform the scans required for accreditation submission and evaluate per the criteria in the MRI Accreditation Phantom Guidance Document

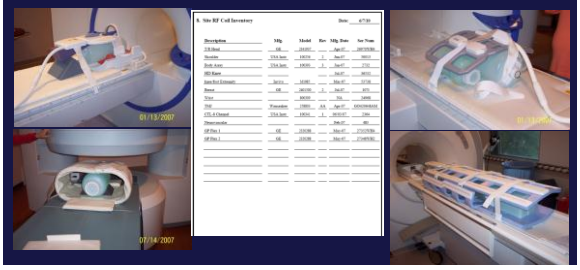
ACR Annual Performance Report Measurements, ct'd

1. Magnetic field uniformity
2. Slice Position Accuracy
3. Slice Thickness Accuracy
4. RF Coil Checks
   a. Volume Coils
      Signal-to-Noise Ratio (SNR)
      Percent Image Uniformity (PIU)
      Percent Signal Ghosting (PSG)
   b. Surface Coils (Coil arrays)
      Maximum SNR
5. Soft Copy (Monitor) Display
   Max and Min Luminance
   Luminance Uniformity
   SMTE pattern evaluation
6. Safety Assessment

Note: Annual Performance Report
1. Must include some form of field uniformity assessment
2. Must have monitor assessment

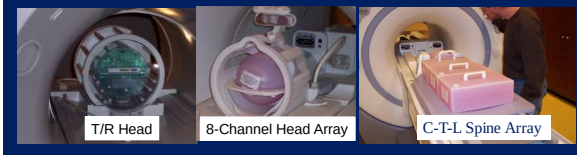
Prior to annual coils checks physicist should:

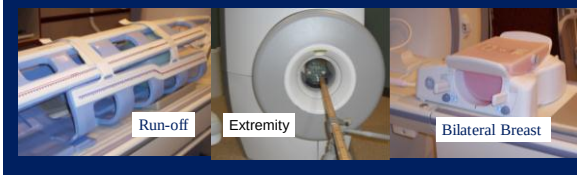
- Inventory and inspect all cables, coils and connector boxes
- Record coil serial number and manufacture date
- Report any findings to site vendor service engineer
- Repeat all weekly/daily technologist's tests
- Perform all scans required for accreditation application



For RF coils tests, choose most appropriate phantom for the coil geometry.

- Positioning and scan technique should be documented and reproducible
- Each individual array element should be tested





Annual Magnetic Field Homogeneity Testing

(2014 Manual provides alternative methods:

- **Spectral FWHM with large sphere** (Only global sensitivity)
- **Phase-Difference Method** (Provides planar map image)
- **Phase-Map Method** (Provides planar map image)
- **Bandwidth-Difference Method**

(Chen, et al Med. Phys. 33 (11), 2006. Note: only sensitive along frequency axis.)

Alternative: For systems that do not allow any of these methods. One may use the service engineer's most recent shim report (< 6 month).

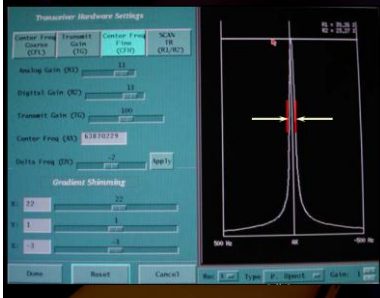
Magnetic Field Homogeneity

Spheres are provided by some vendors and can be used for the homogeneity tests.

The spherical volume diameter should be similar to that cited by the manufacturer's homogeneity specifications.

The sphere should be placed at the field isocenter.

Spectral FWHM Method



With the sphere in the coil, use manual prescan to obtain and display the spectrum of the resonance frequencies.

Determine the "full width at half maximum" (FWHM) of the spectrum and express in units of ppm.

Note: Spectral method provides a global assessment of field homogeneity over the size of the signal producing phantom.

FWHM(ppm) = FWHM (Hz)/63.87 B_0(T)

Phase-Difference Method

Acquire two gradient-echo images with different echo times. Display and store as phase images. Subtract the second phase image from the first to obtain a phase difference image in which each pixel's intensity represents the difference between the phases of the two acquisitions, since the T2 of the solution is constant.

The difference (ΔB_0) between the B_0 field at a given voxel and the reference value at the center of the field of view (FOV) is:

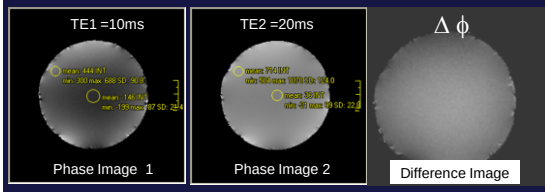
$$\Delta B_0 = (\Delta\phi / \gamma)/(TE_1 - TE_2),$$

where the ΔB_0 is in mT, $\Delta\phi$ is the phase difference in radians, γ is the gyromagnetic ratio (42,576 Hz•mT^{-1} = 267,513 radians per second per mT^{-1} for protons) and the TE values are in units of seconds.

Repeat this procedure to obtain data from other planes.

Determine the greatest difference in any plane between the values of ΔB_0 within circular regions of interest having specific d.s.v. This value divided by the B_0 field strength of the magnet will yield the homogeneity (in ppm) for the specified d.s.v.

Phase-Difference Method

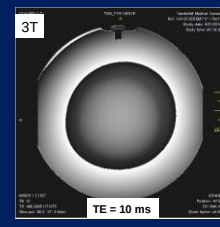


The phase-difference method provides a spatial map of the field homogeneity within the chosen plane. Additional plane orientations should be used to provide a measure of volumetric homogeneity.

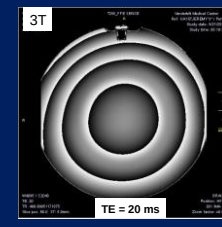
Note: Consult system manufacturer to determine the units used for the value of the phase pixels (e.g. radiansX1000)

Phase-Map Method

Gradient Echo Sequence: TE ~ 1/resonance frequency (ppm)
(e.g. 1 ppm @ 1.5T = 1/63 Hz = 15.6 ms)



TE = 10 ms ~ 0.8 ppm/transition



TE = 20 ms ~ 0.4 ppm/transition

Bandwidth-Difference Method

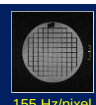

Axial


Sagittal


Coronal

$$H_B(\text{ppm}) = \frac{\text{BW}_1 \cdot \text{BW}_2 \cdot (x_1' - x_2')}{\gamma \cdot B_0 \cdot \text{FOV}_x(\text{BW}_2 - \text{BW}_1)}$$


8 Hz/pixel


155 Hz/pixel


Difference

Note: The BW-difference method is sensitive to homogeneity in the frequency-encode direction only and thus should be repeated at different orientations.


Routine testing of magnetic field homogeneity on clinical MRI systems
Med. Phys. 33 (11), November 2006

The assessment of magnetic field uniformity is required:

1. At the time of equipment installation only
2. Only for systems of field strength ≥ 1T
3. To be performed by the service engineer
4. As part of each annual testing
5. To be ≤ 1.5 ppm

10

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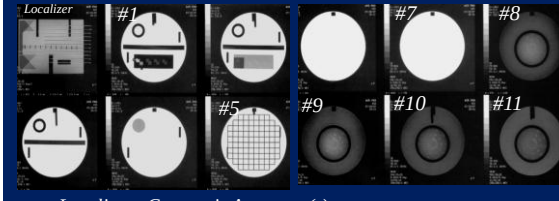
http://www.acr.org/~/media/ACR/Documents/Accreditation/MRI/Requirements.pdf

ACR Large Phantom Analysis

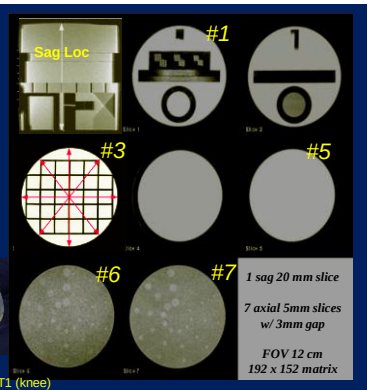
Five sequences: ***ACR T1, Dual-Echo T2, and Site T1 and T2***
(SE 50/500 and SE 20-80/2000 ms, 25 cm, 256X256, multi-slice (11 at 5mm), 1 NEX)



Localizer: Geometric Accuracy (z)
#1) Slice thickness and position, geometric accuracy, high contrast resolution
#5) Geometric accuracy (x,y)
#7) Percent image uniformity (PIU), Percent signal ghosting (PSG)
#8-11) Low contrast object detectability (LCD), and slice position (in #11)
Images courtesy of E.F. Jackson, PhD

ACR Small Phantom
(Extremity Systems)

Sag localizer: Geometric accuracy
#1) Slice thickness and position, geometric accuracy, high contrast resolution
#3) Geometric accuracy
#5) PIU, ghosting (PSG)
#6-7) LCD

1 sag 20 mm slice

7 axial 5mm slices w/ 3mm gap

FOV 12 cm
192 x 152 matrix

Five Sequences
1) ACR Sagittal (20/200)
2) ACR T1 SE (20/500)
3) ACR T2 SE (80/2000)
4) Site T1 (knee)
5) Site T2 (knee)

ACR Guidelines for Phantom Scans

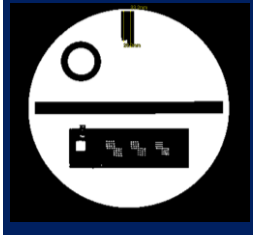
Large Phantom
(FOV = 25 cm, 256X256)

Dimensional accuracy (Sagittal)	148 ± 2 mm
Dimensional accuracy (Axial)	190 ± 2 mm
Slice Thickness	5 ± 0.7 mm
Slice Position	≤ 5mm
Image Uniformity (PIU)	≥ 87.5% (< 3T) ≥ 82.0% (3T)
Percent Signal Ghosting	≤ 2.5%
High-contrast Resolution	1 mm
Low-contrast Detectability Score	≥ 9 (<3T) ≥ 37 (3T)

Small Phantom
(FOV = 12 cm, 152X192)

Dimensional accuracy (Sagittal)	100 ± 2 mm
Dimensional accuracy (Axial)	100 ± 2 mm
Slice Thickness	5 ± 0.7 mm
Slice Position	≤ 5mm
Image Uniformity (PIU)	≥ 87.5% (< 3T)
Percent Signal Ghosting	≤ 2.5%
High-contrast Resolution	0.8 mm
Low-contrast Detectability Score	≥ 9 (<3T)

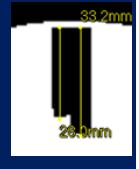
ACR T1 and T2 Slice Position Accuracy



Slice 1

- **Magnify image by 2-4x**
- **WW: min (crisp ends)**
- **WL: not critical ~ ½ mean**
- **Measure bar length difference**
- **Record ½ bar length difference**

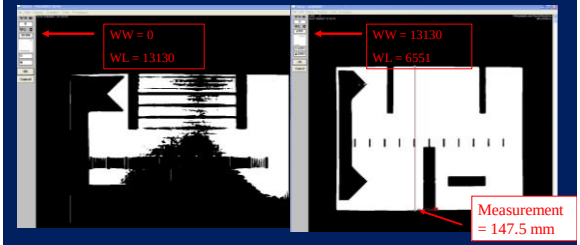
Example:
Slice position error = (33.2mm – 28.0 mm)/2 = 5.2mm/2 = 2.6 mm
Position error = 2.6 mm



Criterion: ≤ 5 mm

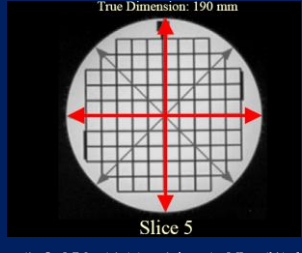
QC Measurement of Geometric Accuracy

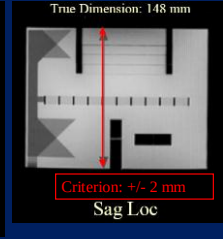
(Sagittal localizer: true dimension 148 mm)



1) Set WW to 1 (minimum) then raise WL until ½ of water is dark
(This value of WL is an estimate of the mean water intensity.)
2) Now set WW to the value of WL determined above and set WL to ½ that value.
3) Make measurements using length/distance tool provided by vendor

Measure and Record for Geometric Accuracy





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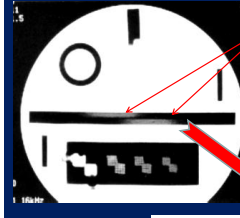
(This value of WL is an estimate of the mean water intensity.)
2) Now set WW to the value of WL determined above and set WL to ½ that value.
3) Make measurements using length/distance tool provided by vendor

Slice Thickness

ACR T1 and T2

Slice 1

Two 10:1 ramps



- **Magnify image by 2-4x**
- **Define two ROIs, one over center of each ramp (entirely within ramp)**
- **Obtain average intensity from the two ROIs**

Slice Thickness

Measurements:
- Set WL to ½ average intensity (~mean)
- Set WW to minimum
- Measure lengths of top and bottom ramps
- Calculate slice thickness

$$\text{Slice thickness} = 0.2 \times \frac{(\text{top} \times \text{bottom})}{(\text{top} + \text{bottom})}$$

Criterion: 5.0 +/- 0.7 mm

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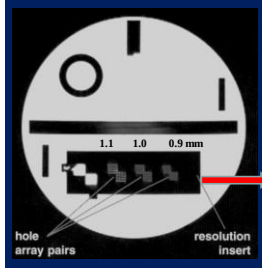
High Contrast Spatial Resolution

ACR T1 and T2



Slice 1

- Turn off gradient distortion correction algorithm (if possible)
- Magnify by 2-4 X
- Use UL for horizontal resolution and LR for vertical resolution
- Must be able to resolve 1.0 mm holes vertically and horizontally
- Set WW and WL for visualization

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Criterion: 1.0 mm

Gradient Distortion Correction Effect on Spatial Resolution

Without Correction

With Correction

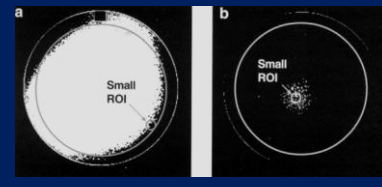
Percent Image Uniformity

ACR T1 and T2

Slice 7

WW: minimum
WL: as needed

Large ROI
(195-205 cm^2)



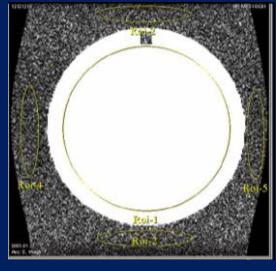
$$\text{Percent integral uniformity (PIU)} = 100 \times \left[1 - \frac{(\text{high} - \text{low})}{(\text{high} + \text{low})}\right]$$

≤1.5 T
Criterion: PIU ≥ 87.5 %

3.0 T
Criterion: PIU ≥ 82.5%

Ghosting

ACR T1



Window and level to make sure ROIs are in the background noise.

(Warping of image space due to gradient nonlinearity corrections.)

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Low Contrast Detectability

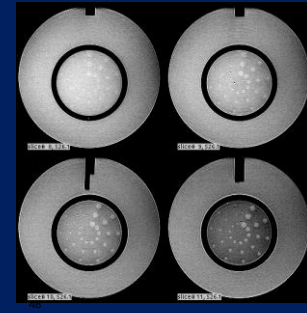
ACR T1 and T2

Slices 8-11
Slice 8: 1.4%
Slice 9: 2.5%
Slice 10: 3.6%
Slice 11: 5.1%

Set WW and WL for visualization

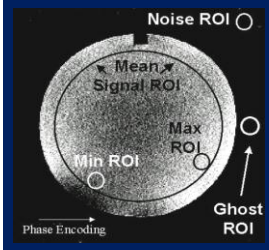
1.5 T or less
Criterion: ≥ 9 spokes

3.0 T
Criterion: ≥ 37 spokes



Volume Coil Measurements

Note: If possible intensity correction algorithms should be off.



Must assess for all coils that are used clinically:

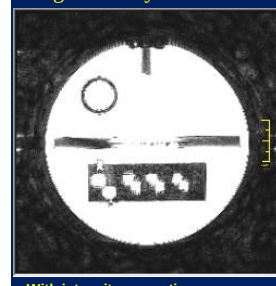
1. SNR* (signal-to-noise ratio)
2. Uniformity (percent image uniformity: PIU)
3. Ghosting ratio

* Note: For multi-element coils using multiple receive channels it may be necessary to use a different method for estimating noise than described in the ACR QC manual.

Use ACR Phantom slice #7

Image compliments of Geoff Clarke, Ph.D.

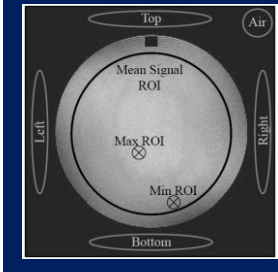
Image Intensity Correction Algorithm used for coil arrays will affect background and the calculated SNR, e.g. SCIC, CLEAR and PURE. Recommend turning off image intensity correction when assessing coil SNR.



With intensity correction

With intensity correction

Volume Coil Measurements: (2014 ACR Manual)



Signal-to-Noise Ratio*

$$SNR = \frac{Mean\ Signal}{\left(\sigma_{air} / \sqrt{2 - \pi/2}\right)} = 0.655 \frac{Mean\ Signal}{\sigma_{air}}$$

Percent Image Uniformity (same)

$$PIU = 100 \bullet \left(1 - \frac{Max\ ROI - Min\ ROI}{Max\ ROI + Min\ ROI}\right)$$

Percent Signal Ghosting (same)

$$PSG = 100 \bullet \left(\frac{|(Left + Right) - (Top + Bottom)|}{2 \bullet Mean\ Signal}\right)$$

AAPM REPORT NO. 100: Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities (2010), One Physics Ellipse, College Park, MD.

*NEMA MS 1-2008: Determination of Signal-to-Noise Ratio in Diagnostic Magnetic Resonance Images (Method 4)
Note: No longer subtracts background and now X 0.655 for Rician noise correction.

SNR Image-Difference Method*

$$SNR = \sqrt{2}\,\frac{Mean\ Signal}{\sigma_{diff}}$$

√2 corrects for error propagation.

AAPM REPORT NO. 100: Acceptance Testing and Quality Assurance Procedures for Magnetic Resonance Imaging Facilities (2010), One Physics Ellipse, College Park, MD.

*NEMA MS 1-2008: Determination of Signal-to-Noise Ratio in Diagnostic Magnetic Resonance Images (Method 1)

When evaluating high-contrast spatial resolution, it is recommended that:

1. The smallest FOV be used
2. Gradient distortion correction be turned off
3. The largest available acquisition matrix be used
4. Receive-only coils should not be use

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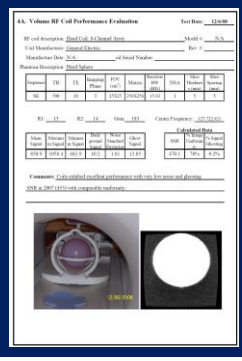
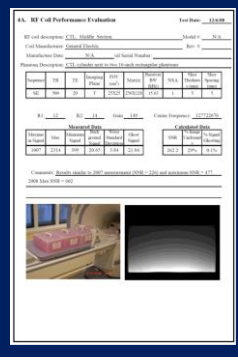
2. Gradient distortion correction be turned off
3. The largest available acquisition matrix be used
4. Receive-only coils should not be use

Reference: **The Physics of Clinical MR Taught Through Images**
Val M. Runge, Wolfgang R. Nitz, Stuart H. Schmeets, (2009) Thieme pg 170.

Volume Coil Report Surface Coil Report

Note: Reports should include assessment relative to previous performance or assessment relative to similar systems.

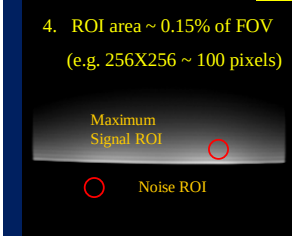


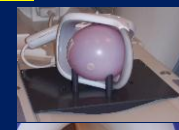


Surface Coil Measurements

1. Use a phantom that most closely matches the coil geometry
2. Carefully record the geometry (best recorded with a photograph) so that it can be reproduced in subsequent measurements.
3. Measure and record the maximum SNR
4. ROI area ~ 0.15% of FOV

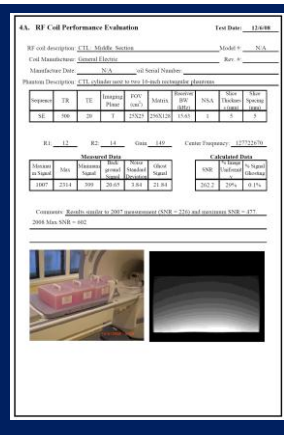
   (e.g. 256X256 ~ 100 pixels)





Example:

Surface Coil Report



Multi-element coils:

New guidelines recommend that each element be checked.

Phantom over coil element 3

Phantom over coil element 4

In most systems, it is possible to select individual elements and test as surface coils.

C-T-L Spine Array

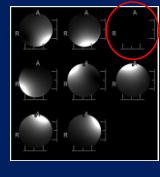
Run-off

Bilateral Breast

Testing Coil Arrays

The 2014 ACR MRI Manual recommends that the images from each coil element be reconstructed and displayed individually to check for malfunctioning array elements. This is increasingly important with high-density arrays. A single SNR and/or uniformity measurement often will not detect a single bad element (or even a few bad elements). Some scanners provide an easy option, selectable by the technologist or other operator, to allow for the reconstruction and display of the image from each element. On other systems, service or research mode access is required.

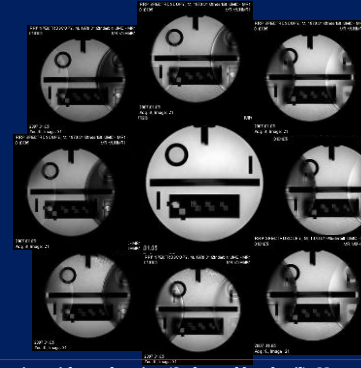
PIU = 93%



Dead Coil Element in 8-channel array

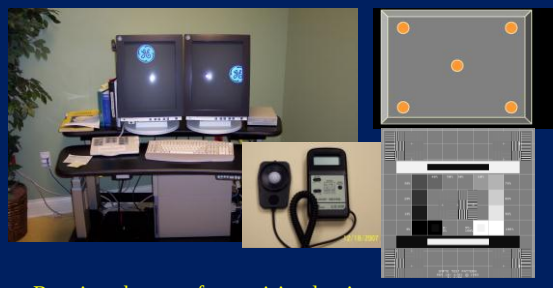
Images Courtesy of Ed Jackson

SENSE Factor 2



Parallel Imaging with acceleration (8-channel head coil): Not currently addressed

Soft Copy Display



Requires the use of a precision luminance meter to make measurements from the monitor screen

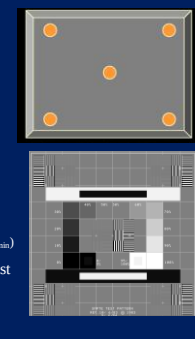
Soft Copy Displays

Four Tests:

1. Max and Min luminance (L_{max} and L_{min})
2. Luminance uniformity
3. Resolution using SMPTE pattern
4. Spatial accuracy (SMPTE)

Specifications:

1. Max luminance (WL/WW = min): > 90 Cd/m^2
2. Min luminance: < 1.2 Cd/m^2
3. Uniformity: % difference = 200* (L_{max}- L_{min})/(L_{max}+ L_{min})
4. Resolution: display bar pattern of 100% contrast
5. Spatial accuracy: lines straight within +/- 5mm



Annual Medical Physicist's Site Safety Assessment (Checklist)

- Site Access Restrictions (MR Zones)
- Documented MR Safety Education/Training for all personnel
- Patient and non MR Personnel Screening
- Pediatric Patient Policy
- Designated MR Safety Officer
- Disaster Policy
- Quench Policy
- Cryogen Safety Policy
- Acoustic Noise Policy
- Pregnancy Policy
- Contrast Agent Safety Policy
- Sedation Policy
- Thermal Burns Policy
- Emergency Code Procedures
- Device and Object Screening and designation of MR Safe/MR Conditional status
- Procedures for Reporting MR Safety Incidents or Adverse Incidents
- Patient Communication
- Infection Control

Criteria for Compliance

1. Written policies are present and are being reviewed and updated on a regular basis.
2. Facility has appropriate signage and methods of controlled access.
   Documentation of regular MR safety training for each facility staff member

Complete Medical Physicist/MR Scientist Equipment Performance testing should be performed:

1. At least quarterly
2. Whenever a new coil is installed
3. After the report of an RF burn
4. Upon installation
5. Whenever SNR falls below the action level

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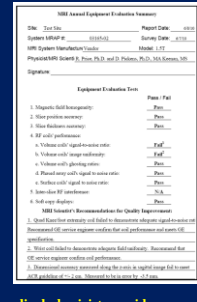
Reference: ACR website www.acr.org

http://www.acr.org/~/media/ACR/Documents/Accreditation/MRI/Requirements.pdf

Medical Physicist's Annual Equipment Performance Report

Tech QA Assessment **Summary Sheet**



It is very important that the consulting medical physicist provide recommendations for Quality Improvement and maintain frequent contact with the site QC Technologist to monitor the QC program and to assist in corrective actions.

Conclusion and Comments

- **The 2014 ACR MRI Quality Control Manual has relatively modest changes from the 2004 version.**
- **There is an emphasis on MRI safety and infection control to minimize patient risk.**
- **An attempt was made to embrace NEMA standards and to identify several alternate methods for image parameter assessment.**
- **Currently the revised manual does not identify a specific method for testing parallel imaging. However, when a generally accepted method is identified, it will be incorporated into the electronic manual by means of an annual update.**