

# *ACR Accreditation Update in MRI*



*Whole Body Systems*



*Extremity (MSK)*



*Dedicated Breast*

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# MRI Accreditation Update

1. ACR MRI Accreditation: Overview, History and Role of the Medical Physicist
2. CMS/MIPPA Requirements
3. Other Accreditation Organizations
4. ACR MRI Application Specifics  
(Whole-body modular, Extremity and Breast)
5. Revised ACR MRI Quality Control Manual  
(Radiologist, Technologist and Medical Physicist Sections)
6. Accreditation and MRI Safety

# ACR MRI Accreditation Program History

[www.acr.org/QualitySafety/Accreditation/MRI](http://www.acr.org/QualitySafety/Accreditation/MRI)

Goals of the ACR MRI Accreditation Program are to set quality standards for “best practice” and to help continuously improve the quality of patient care.

Primary components of the ACR program are the evaluation of:

1. Qualifications of all personnel (Physicians, Physicists and Technologists)
2. Equipment performance
3. Effectiveness of quality control measures
4. Quality of clinical images

## ACR Milestones

- 1996: Voluntary Whole-body/Cardiac MRI accreditation with “Large” QA phantom
- 2008: Modular program (Head, Spine, MSK, Body, MRA, Cardiac)
- 2008: “Small” phantom for dedicated extremity systems.  
(Note: Not required for MSK module accreditation)
- 2010: Breast MRI Accreditation (Mammography program not MRI program)
- 2012: Required site visit once during each 3-year accreditation cycle

# *Role of the Medical Physicist*

## *ACR Technical Standard for Diagnostic Medical Physics Performance Monitoring of Magnetic Resonance Imaging (MRI) Equipment (revised 2009, Resolution 10)*

*I. Qualifications and Responsibilities of Personnel*

*II. System Performance Characteristics to be Monitored*

*A. Acceptance Testing*

*B. Annual Equipment Performance Testing*

*C. Quality Control and Safety Program*

*D. Written Survey Reports and Follow-up Procedures*

AAPM REPORT NO. 100



AAPM  
Report  
No. 100

Acceptance Testing  
and Quality Assurance Procedures  
for Magnetic Resonance Imaging Facilities

## *MRI Accreditation Program Requirements (7/2/13)*

## *ACR Guidance Document for Safe MR Practices: 2013*

A screenshot of the American College of Radiology (ACR) website. The header includes the ACR logo with the tagline 'QUALITY IS OUR IMAGE' and the website address 'www.acr.org' in a red box. Navigation links include 'LOGIN', 'RESIDENTS', 'ABOUT US', 'CAREER CENTER', 'PATIENT INFO', 'MEDIA ROOM', 'MY PROFILE', and 'JOBS AT ACR'. A search bar is present with 'SEARCH SITE' and 'SEARCH INTERNET' buttons, and a note '[ Powered by Google ]'. The main content area is titled 'Magnetic Resonance Imaging (MRI)' and features a banner for 'Practice Guidelines &amp; Technical Standards' with an image of MRI scans. A sidebar on the left contains a 'Print Page' button and a list of links: 'ACR Homepage', 'Q&amp;S Resources Home', 'Guidance Resources Home', 'Appropriateness Criteria Home', and 'Practice Guidelines and Technical Standards Home'.

<b>ACR Annual Performance Tests</b> (Red indicate new 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	<i>Geometric Accuracy</i>	X	X
5	<i>High-Contrast Spatial Resolution</i>	X	X
6	<i>Low-Contrast Detectability</i>	X	X
7	Artifact Evaluation	X	X
8	Hardcopy (Film) QC (if applicable)	X	X
9	Visual Checklist	X	X
10	<i>Percent Signal Ghosting (PSG)</i>		X
11	<i>Image Intensity Uniformity (PIU)</i>		X
12	<i>Magnetic Field Homogeneity</i>		X
13	<i>Slice Position Accuracy</i>		X
14	<i>Slice Thickness Accuracy</i>		X
15	Radiofrequency Coil Checks (SNR for all coils used clinically)		X
16	Soft Copy (Monitor) QC (Luminance, uniformity and SMTE)		X
17	<b>MR Safety Program Assessment</b>		X

As part of annual testing, physicist must repeat and evaluate the weekly Tech QC measurements as well as the sequences required for accreditation submission.

Note: Interslice RF cross-talk test has been eliminated.

# CMS/MIPPA Requirements

The Centers for Medicare and Medicaid Services (CMS/MIPPA)\* requires that all facilities providing Advanced Diagnostic Imaging (ADI)\*\* services that are billed under Part B of the Medicare Physician Fee Schedule must be accredited by one of the four CMS approved accreditation organizations by January 1, 2012. Accreditation requirements specifically do not apply to the physician's image interpretation.

American College of Radiology (ACR)

Joint Commission (JC)

Intersocietal Accreditation Commission (IAC)

RadSite (RS) (2013)

\* *MIPPA: Medicare Improvements for Patients and Providers Act*

\*\* *ADI: MRI, CT and Nuclear Medicine/PET*





# Revised Requirements for Diagnostic Imaging Services

APPLICABLE TO HOSPITALS AND CRITICAL ACCESS HOSPITALS

**Effective July 1, 2014 (Extended to 2015)**  
(Very similar to current ACR standards.)

## Standard EC.02.04.03

The [critical access] hospital inspects, tests, and maintains medical equipment.

**A 20.** © For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: At least annually, a diagnostic 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. The evaluation includes the use of phantoms to assess the following imaging metrics:

- Image uniformity for all radiofrequency (RF) coils used clinically
- Signal-to-noise ratio (SNR) for all coils used clinically
- Slice thickness accuracy
- Slice position accuracy
- Alignment light accuracy

- High-contrast resolution
- Low-contrast resolution (or contrast-to-noise ratio)
- Geometric or distance accuracy
- Magnetic field homogeneity
- Artifact evaluation

(MRI) services: The annual performance evaluation conducted by the diagnostic medical physicist includes testing of image acquisition display monitors for maximum and minimum luminance, luminance uniformity, resolution, and spatial accuracy.

**Note:** This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.



MRI | ICAMRL

[www.intersocietal.org/MRI/Standards](http://www.intersocietal.org/MRI/Standards)

## **The IAC Standards and Guidelines for MRI Accreditation**

### Accreditation Areas

- Cardiovascular MRI
- Breast MRI
- Body MRI  
(Chest, abdomen, pelvis, extremity)
- Musculoskeletal MRI
- Neurological MRI
- MRA

### Key Features

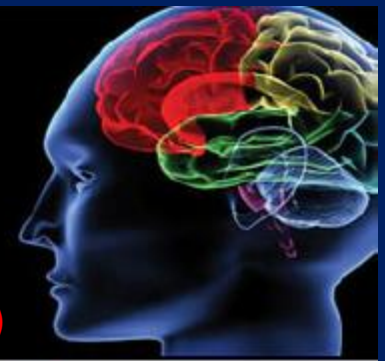
1. Performance referenced to manufacturer's specifications
2. Medical Physicist qualifications not specified
3. No specific phantom identified
4. Safety Assessment Required





# RadSite MAP Accreditation Standards

(MAP v 2.1)



[www.RadSiteQuality.com](http://www.RadSiteQuality.com)

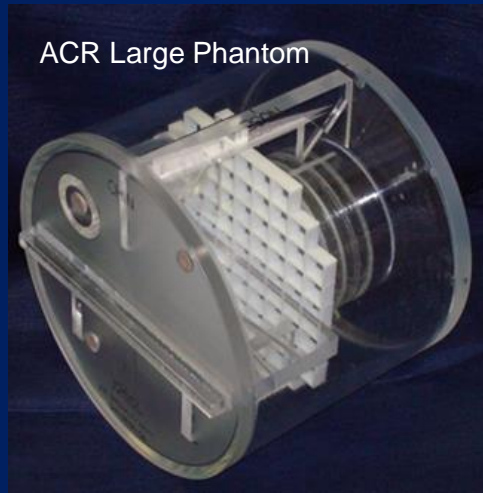
## Areas of Accreditation

- Neurologic
- Musculoskeletal
- Body
- Cardiovascular
- Breast Imaging
- MR Angiography (MRA)
- MR Spectroscopy

## Key Features

1. Personnel qualifications and performance guidelines similar to ACR.
2. Phantom images may use either ACR or MagPhan SMR170
3. Safety Assessment

ACR Large Phantom



Cylindrical Magphan® SMR170



# The ACR MRI accreditation program requires:

20% 1. Sites to provide breast MR imaging

20% 2. Magnets to be  $\geq 1.0\text{T}$

20% 3. A verification site visit every year

20% 4. CMS accreditation

20% 5. Annual system performance testing

# The ACR MRI Accreditation program requires:

1. Sites to provide breast MR imaging
2. Magnets to be  $\geq 1.0\text{T}$
3. A verification site visit every year
4. CMS accreditation
5. Annual system performance testing

Reference: ACR MRI Accreditation Requirements

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

# *ACR Accreditation Application: No Significant Changes*

*The accreditation process consists of two phases:*

*Phase 1: Account Activation (Must be completed online.)*

*Phase 2: Application (Image submission either online or mailed CDs.)*

*For the modular whole-body and extremity magnets the Full Application requires:*

- Phantom and Clinical Images*
- Physicist's Equipment Performance Report for each magnet (< 1 year)*  
*and last quarter QC documents*

*Note: At the present time the Breast MRI application does not require phantom images but does require the Physicist's Equipment Performance Report and QC documents.*

# ACR Account Activation

<https://acredit.acr.org/>

Version: 1.0.0.13601

**ACR**  
AMERICAN COLLEGE OF  
RADIOLOGY

**ACredit**

E-mail Address:

Password:

☐ Remember me next time

[Register](#)

[Forgot Password?](#)

When completed and accepted, you will receive an email indicating that your online “testing package” is available.

## Testing Package Window

Instruction Form

Fields marked X are the incomplete sections.

- ☒ Quality Assurance Questionnaire
- ☒ UNIRF OF ADAC C-PET/250 GANTRY 1
- ☒ Annual Physics Evaluation
- ☒ Clinical TID (WB Bone)
- ☒ Clinical TID (Spot Bone)
- ☒ Phantom Site Scanning Data Form

This section of the page is used to upload the images electronically.

- ☒ Upload Files
- ☒ Upload Images
- ☒ Submit

Fields marked with a green check are the completed sections.

Note

- ☒ Completed
- ☒ Not completed
- ☒ Not available
- ☒ Information

## SECTION 1

### PRACTICE SITE INFORMATION

- ☐ Practice site name, location and mailing addresses, appointment and fax telephone numbers
- ☐ Names of the practice site supervising physician and practice site administrator
- ☐ Telephone number and e-mail address for the practice site administrator
- ☐ Are the interpreting physicians for the site radiologists, non-radiologists or both?

#1

### LEGAL FORM

- ☐ Name and title of the practice site president, CEO or owner that will sign the agreement

### GENERAL MODALITY INFORMATION

- ☐ List of all imaging modalities offered at the practice site (not just those for which you are applying)
- ☐ ACR accreditation ID numbers for any modalities at this site that are already approved or in process
- ☐ The average number of exams performed per year for modalities that are already approved, in process or for which you are applying

## SECTION 2

### PEER REVIEW INFORMATION

- ☐ Does the site's group of interpreting physicians participate in ACR RADPEER or eRADPEER or an equivalent peer review program? (Please see the program requirements for more information.)
- ☐ If RADPEER, the RADPEER number
- ☐ If RADPEER or an equivalent peer review program, the percentage of images reviewed per physician per year.

### MODALITY INFORMATION

For each modality for which the site is applying.

- ☐ Names and e-mail addresses of the supervising physician(s) and technologist contact person(s)
- ☐ Telephone number for the technologist contact person(s)
- ☐ Number of units (per modality)
- ☐ Basic information for each unit: Unit room #, manufacturer name, model name, serial number, year manufactured, date of last equipment evaluation/physics survey
- ☐ Modality-specific unit information
  - MRI: Magnetic field strength and operating location
  - Breast Ultrasound: Transducer frequency and the type of array
  - Nuclear Medicine: Number of heads
  - Stereotactic Breast Biopsy: Collaborative or independent setting, add-on or prone table and type of recording system
  - Ultrasound: Operating location and the type of primary recording system

#2

NOTE: In addition, some modalities require the site to select examinations for submission. If the person completing the online application is not familiar with the examinations performed at the site for a specific modality, they should consult their modality-specific technologist contact person or supervising physician.

## SECTION 3

### PERSONNEL INFORMATION

- ☐ List of physicians, technologists and medical physicists/MR scientists for the modalities for which the site is applying along with their certifications/degrees
- ☐ Primary specialty of physicians and if applicable, their ACR member number

### PAYMENT INFORMATION

- ☐ If paying by credit card: card type, cardholder's name, card number and expiration date

#3



## ACR Accreditation User Instructions for Electronic Submission of Images

- ✓ Facility Information
- ✓ Survey Agreement
- ✓ Accredited Modalities

### Section 2

✗ MRAP

### Section 3

- ✗ Personnel
- ✗ Payment
- ✗ Submit

### Note

- ✓ Completed
- ✗ Not completed

Please describe the Magnetic Resonance Imaging units at this facility location.

Unit#01

Room Location or "Mobile"	<input type="text" value="test room"/>
Manufacturer	<input type="text" value="General Electric"/>
Model Name	<input type="text" value="3.0T SIGNA HD"/>
Serial Number	<input type="text" value="11111"/>
Year Manufactured	<input type="text" value="2010"/>
Date of Last Equipment Evaluation/Physics Survey	<input type="text" value="01 / 19 / 2012"/>
Type of Submission for Clinical Exams	<input type="text" value="[Select]"/>
Type of Submission for Non-Clinical Exams	<input type="text" value="[Select]"/>
Submission Method	<input type="text" value="Film"/> <input type="text" value="CD"/> <input type="text" value="Electronic"/>
Room Location	<input type="radio"/> Fixed <input type="radio"/> Fixed Trailer <input type="radio"/> Mobile Tr
Is this magnet only capable of extremity examinations?	<input type="radio"/> Yes <input checked="" type="radio"/> No
Type of Magnet	<input type="text" value="Whole Body"/>

Select submission  
as Electronic from  
the drop down.



# Phantom Images Required for Accreditation Application: **No Change**

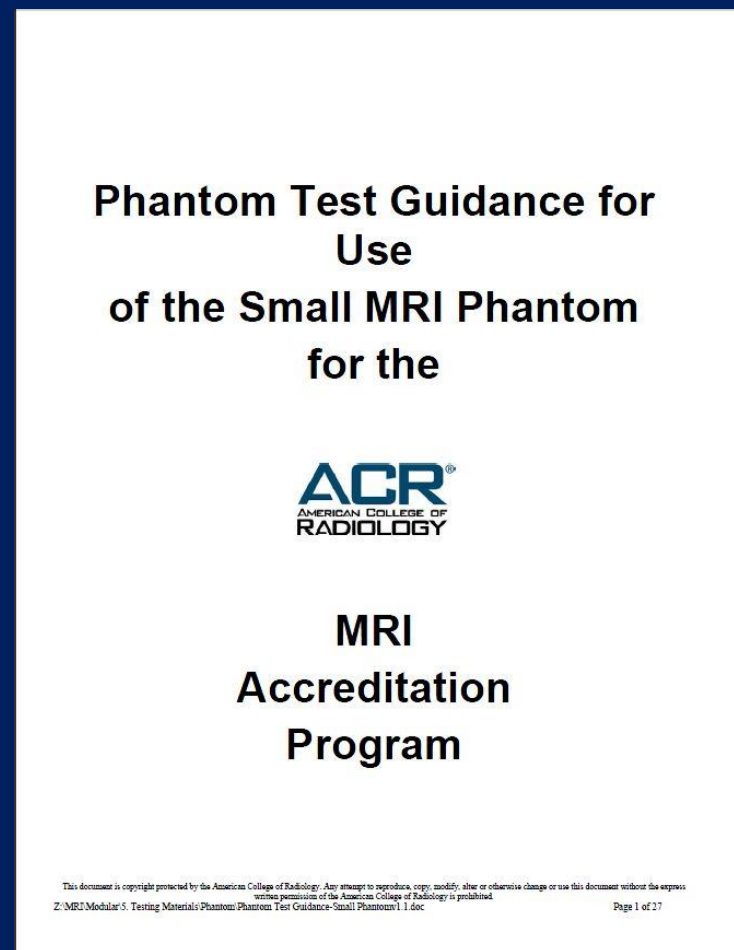
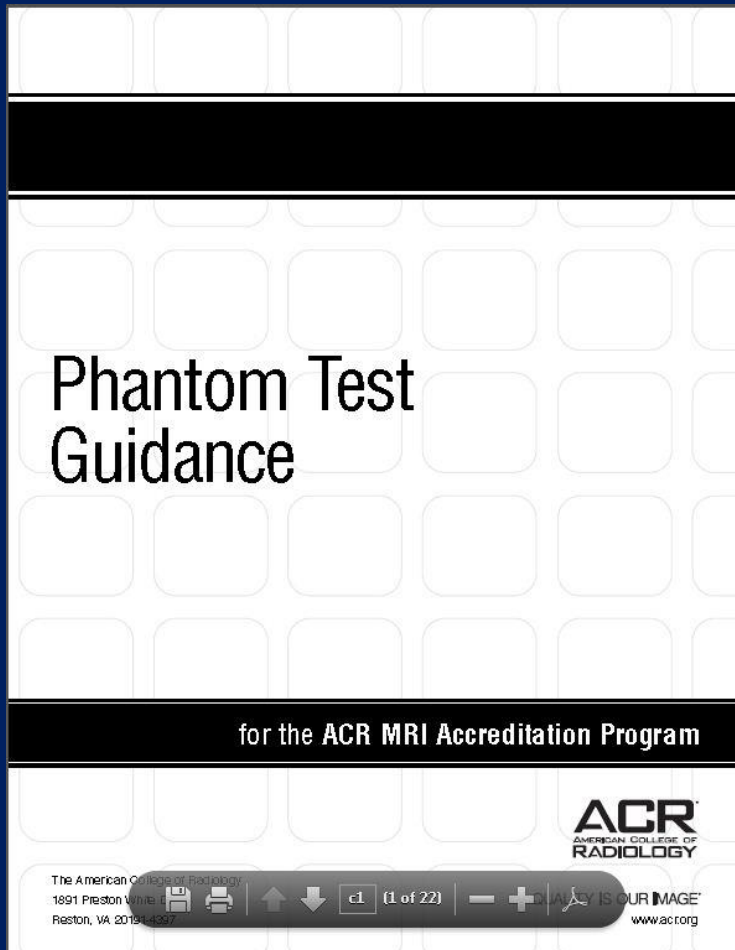
- Large Phantom

- Sagittal Localizer
  - TR/TE = 200/20 ms, 25 cm FOV, 256 x 256, 1 @20 mm, 1 NEX, 0:56
- ACR T1 Axial Series
  - TR/TE = 500/20 ms, 25 cm FOV, 256 x 256, 11 @5 mm slices, 1 NEX, 2:16
- ACR T2 Axial Series
  - TR/TE1/TE2 = 2000/20/80 ms, 25 cm FOV, 256 x 256, 11 @5 mm slices , 1 NEX, 8:56  
(same locations as for ACR T1 series)
- Site T1 Brain Series (11 @5 mm slices)
- Site T2 Brain Series (11 @5 mm slices)

- Small Phantom

- Sagittal Localizer
  - TR/TE = 200/20 ms, **12 FOV, 152/192**, 1 @20 mm, 1 NEX, 0:32
- ACR TE Axial Series
  - TR/TE = 500/20 ms, **12 FOV, 152/192, 7 @5 mm slices**, 1 NEX, 1:16
- ACR T2 Axial Series
  - TE/TE = 2000/80 ms, **12 FOV, 152/192, 7 @5 mm slices**, 1 NEX, 5:04
- Site T1 Knee Series (7 @5 mm slices)
- Site T2 Knee Series (7 @5 mm slices)

# Large and Small Phantom Test Guidance Document



Available at [www.acr.org](http://www.acr.org)

# Clinical Examination Choices by Module

Examination choices for MR Accreditation by module (specialty examinations denoted by asterisk*)		
Head/Neck	Spine	MSK
<ul style="list-style-type: none"> <li>• Brain for transient ischemic attack (TIA)</li> <li>• Internal auditory canal (IAC/temporal bone) for hearing loss</li> <li>• Brain for suspected demyelinating disease*</li> <li>• Pituitary with dynamic contrast enhancement*</li> <li>• Orbits for vision loss*</li> </ul>	<ul style="list-style-type: none"> <li>• Lumbar Spine</li> <li>• Thoracic Spine</li> <li>• Cervical Spine*</li> <li>• Cervical Spine with contrast for intramedullary disease*</li> </ul>	<ul style="list-style-type: none"> <li>• Knee such as for internal derangement</li> <li>• Shoulder such as for internal derangement</li> <li>• Wrist such as for internal derangement*</li> <li>• Elbow such as for internal derangement*</li> <li>• Forefoot for Morton's neuroma*</li> </ul>
Body	MRA	Cardiac
<ul style="list-style-type: none"> <li>• Male pelvis such as for prostate cancer</li> <li>• Renal</li> <li>• Hepatobiliary to Include MRCP*</li> <li>• Female pelvis such as for uterine or adnexal disease*</li> </ul>	<ul style="list-style-type: none"> <li>• Brain</li> <li>• Carotid</li> <li>• Thoracic aorta</li> <li>• Distal peripheral runoff</li> <li>• High resolution arch and carotid*</li> <li>• Abdomen for renal artery stenosis *</li> </ul>	<ul style="list-style-type: none"> <li>• Black blood</li> <li>• Basic</li> <li>• Delayed enhanced cine 1</li> <li>• Delayed enhanced cine 2</li> <li>• Delayed enhanced cine + black blood*</li> </ul>

**MRI Accreditation Program  
Clinical Image Quality Guide**



[www.acr.org](http://www.acr.org)

Typical requirements: 4-6 exams per scanner depending upon the number of modules. Exams must include a “specialty” exam.

# Breast Magnetic Resonance Imaging (MRI) Accreditation Program Requirements



OVERVIEW .....	1
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**At the present time there is no specific ACR MRI phantom.**

**For Breast MRI Accreditation, the Medical Physicist/MR Scientist has the added responsibility of choosing the phantom to be used for the weekly QA measurements and determining the specifics of the QC program.**

**Currently, the ACR Breast MRI Accreditation application does not require phantom images.**

**However because of the specific and detailed requirements for the clinical image acquisition parameters, the Medical Physicist has an important roll in the submission process to confirm that the images meet the technical requirements.**

- A. Required items for testing:
1. [MRI Equipment Evaluation Summary](#) form (also see page 131 in the *2004 ACR Magnetic Resonance Image Quality Control Manual*)
  2. [Evaluation of Site's Technologist QC Program](#) form (also see page 129 in the *2004 ACR Magnetic Resonance Image Quality Control Manual*)
  3. Identification labels to be affixed to the forms
- B. Compliance with the ACR requirements for the medical physicist/MR scientist's Annual MRI System Performance Evaluation and QC:
1. The **entire**, most recent **Annual System Performance Evaluation** report that includes:
    - ☐ A completed **MRI Equipment Evaluation Summary** form signed by the medical physicist/MR scientist (with a survey date within 1 year of the application date for ACR accreditation)
    - ☐ A completed **Evaluation of Site's Technologist QC Program** form
    - ☐ **All** data pages
  2. **Corrective action** taken if the medical physicist/MR scientist's Annual System Performance Evaluation noted any problems (i.e., test failures or data outside of action limits)

## CLINICAL IMAGES

- A. Required items for testing:
1. [Breast MRI Test Image Data](#) form to record your data for the online submission
  2. Identification labels to be affixed to the clinical image discs and the Test Image Data section printout
- B. Select clinical images for accreditation:
1. Review the [Program Requirements](#) and [Clinical Image Quality Guide](#) for guidance on image quality.
  2. Submit 1 case with a **known, enhancing, biopsy-proven carcinoma** clearly visible in the breast parenchyma. Indicate its **laterality and location** on the form.

**Note:** Application now only requires submission of a biopsy-proven CA patient. There is currently no specific requirement for phantom images with the breast MRI application. However, the ACR does require submission of most recent Medical Physics report and phantom QA measurements with a phantom. The specifics of the QA program and the phantom is to be determined by the Medical Physicist.



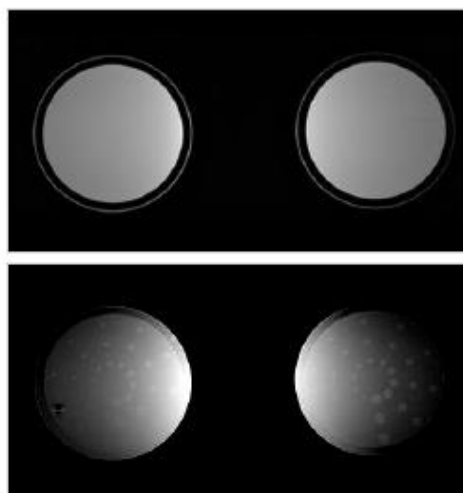
# Breast Weekly QC Measurements

## ■ Daily/weekly QC:

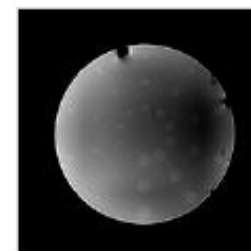
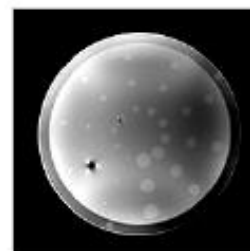
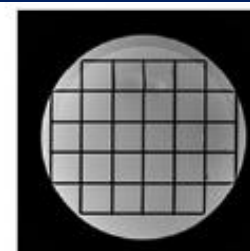
- Choice of phantom and action criteria is up to facility. Decision made by “qualified medical physicist/MR scientist in cooperation with the system vendor”.
  - Large ACR phantom in head coil
  - Dedicated breast MR systems may use small ACR phantom in breast coil.
  - Other vendor-supplied phantom



Small ACR phantoms  
Bilateral mode



Small ACR phantom  
Unilateral mode





ACR Breast Accreditation Clinical Images (review Dicom header)  
 The Medical Physicist will need to help the site determine some of the required information, e.g. slice thickness, phase and frequency-encoding steps and FOV.

Parameters	T2-Weighted/Bright Fluid Series	Multi-Phase T1-Weighted Series		
		Pre-Contrast T1	Early Phase (1 <sup>st</sup> ) Post-Contrast T1	Delayed Phase (last) Post-Contrast T1
Sequence name/type				
Sequence #				
2D or 3D sequence ( <i>check one</i> )	<input type="checkbox"/> 2D <input type="checkbox"/> 3D	<input type="checkbox"/> 2D <input type="checkbox"/> 3D	<input type="checkbox"/> 2D <input type="checkbox"/> 3D	<input type="checkbox"/> 2D <input type="checkbox"/> 3D
Slice orientation				
Acquisition time (min, sec)	min, sec	min, sec	min, sec	min, sec
Slice thickness (mm) (not interpolated)	mm	mm	mm	mm
Interslice gap (mm)	mm	mm	mm	mm
Total number of slices				
FOV <sub>phase-encoding</sub> (mm)	mm	mm	mm	mm
FOV <sub>frequency-encoding</sub> (mm)	mm	mm	mm	mm
N <sub>p</sub> (# of phase-encoding steps)				
N <sub>f</sub> (# of frequency-encoding steps)				
# Acquisitions per phase-encoding step (NEX)				
TE (msec)	msec	msec	msec	msec
TR (msec)	msec	msec	msec	msec
Flip Angle (degrees)		degrees	degrees	degrees
T1 ( <i>only applicable for STIR sequences</i> )	msec <input type="checkbox"/> NA			

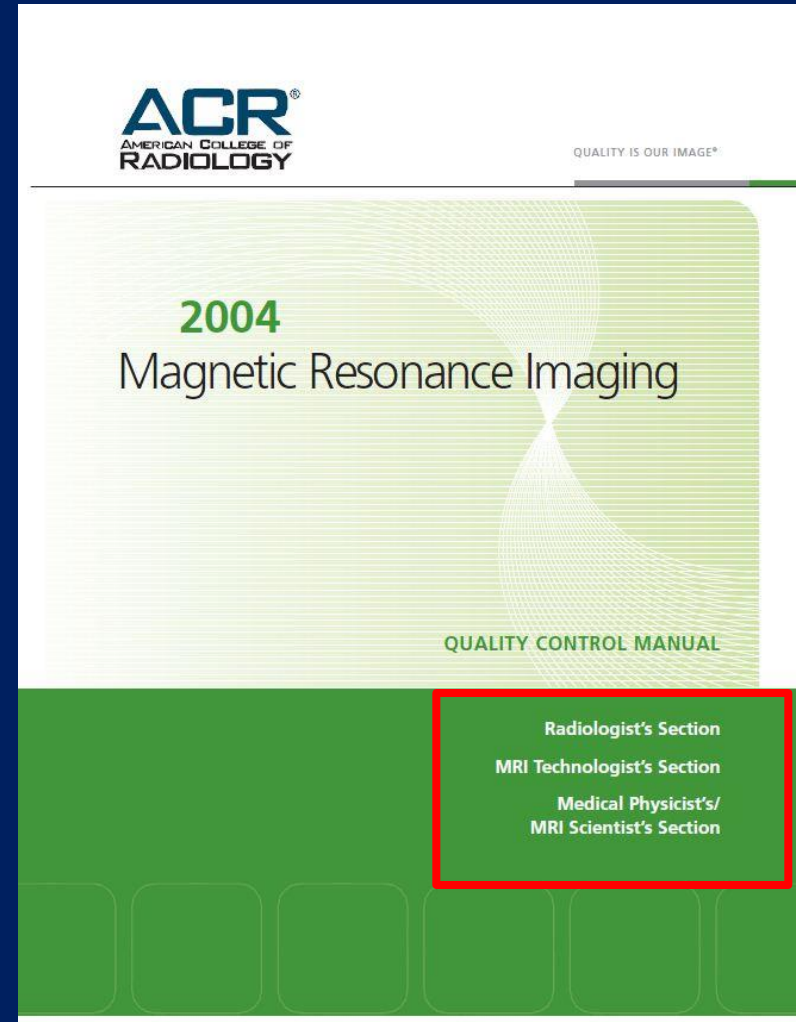
For the pre-contrast and post-contrast T1-weighted series, the following parameters **must** be met:

Sequence	Slice Thickness	Gap	Maximum Recommended In Plane Pixel Dimension for Phase and Frequency
Sagittal, Axial and/or Coronal	≤3 mm	0 mm	≤1 mm

# Revised ACR MRI QC Manual

- **Minor changes from the 2004 version. Changes primarily for clarification with more detail on testing procedures for both large and small phantoms. There are added optional methods for SNR and field homogeneity and there is a greater emphasis on MRI safety\*.**
- **Updated version to be released in 2014. Electronic with FAQs and annual update**

\*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.

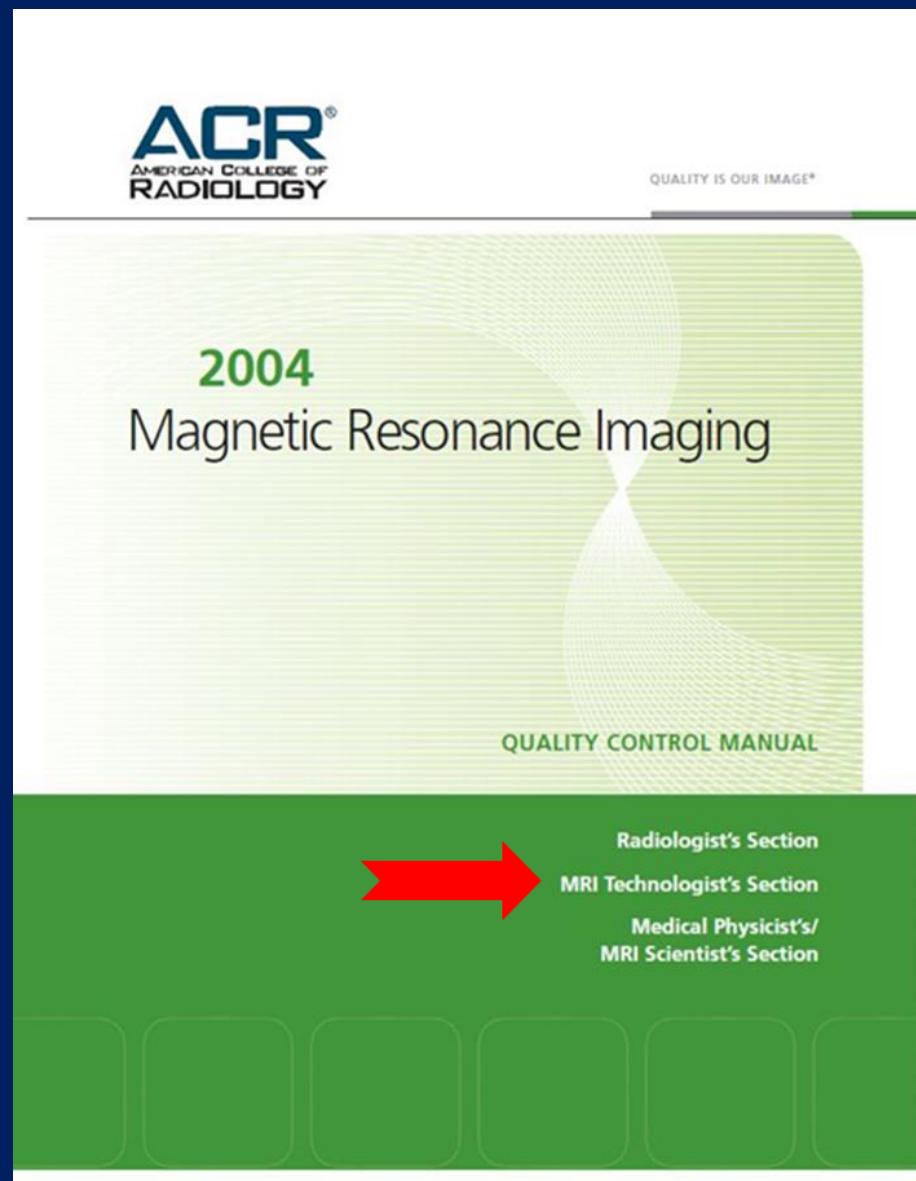


# MR Technologist's Section

## Technologist weekly/daily QC tests:

**New (large and small phantoms)**

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



# Weekly Visual Inspection

- Check patient table, patient communication, patient “panic button”, table movement, laser alignment and all light indicators

“If the table positioning system functions properly and the center of the sagittal image is within  $\pm 2$  mm of the central grid structure on the phantom, enter “YES” in column 2 “Table OK?” of the Data Form for Weekly MRI Equipment Quality Control .”

- 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

The ACR MRI accreditation program requires the technologist to make a weekly assessment of:

20% 1. Slice thickness accuracy

20% 2. Percent image uniformity

20% 3. Low-contrast detectability

20% 4. Magnetic field homogeneity

20% 5. Five-gauss line location

The ACR MRI accreditation program requires the technologist's to make a weekly assessment of:

1. Slice thickness accuracy
2. Percent image uniformity
3. Low-contrast detectability
4. Magnetic field homogeneity
5. Five-gauss line location

*Reference: ACR website [www.acr.org](http://www.acr.org)  
ACR MRI Quality Control Manual  
Technologist's Section*



# 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

# 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*

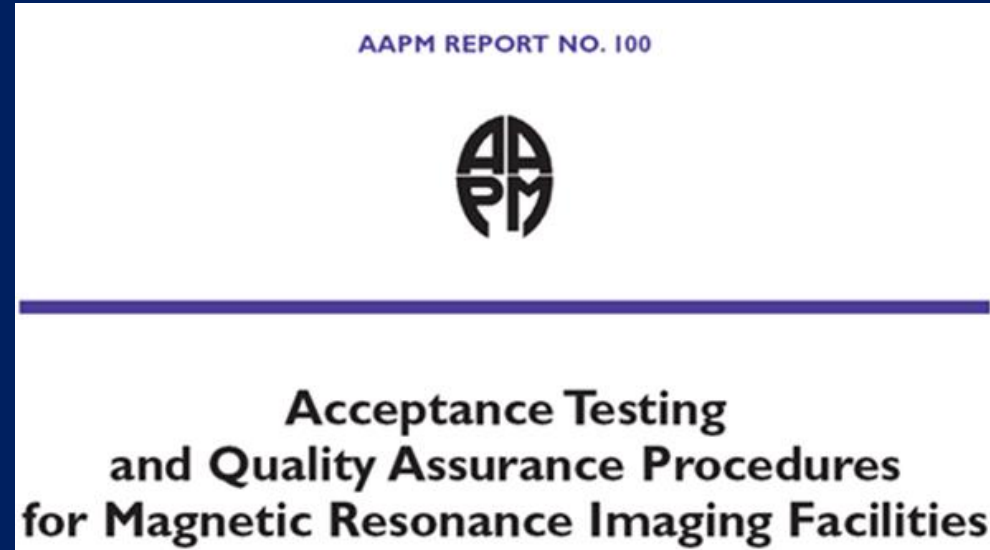
*Signal-to-Noise Ratio (SNR)*

*Percent Image Uniformity (PIU)*

*Percent Signal Ghosting (PSG)*

*High-contrast spatial resolution*

*Low-contrast detectability*



## 5. *Advanced MR System Tests*

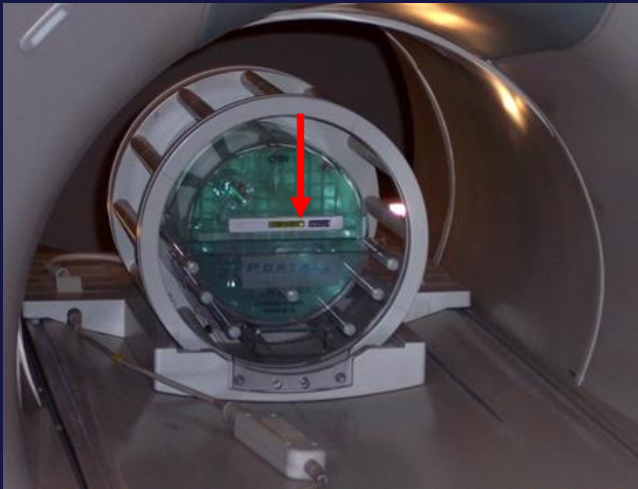
*Ultrafast (EPI) Tests (N/2 ghosting and spatial distortion)*

*Spectroscopy Tests (VOI position accuracy and spectral quality)*

# QC Phantom Selection

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

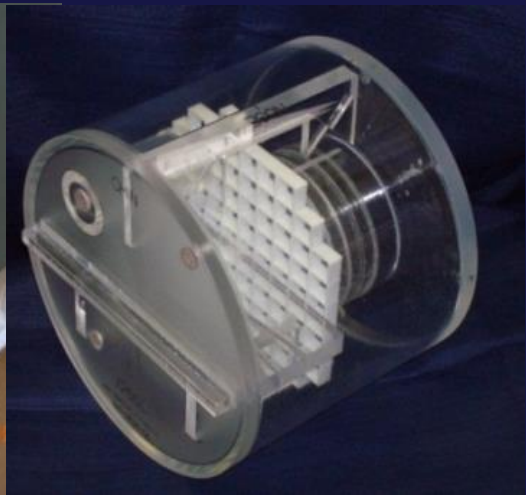
- Whole body scanners – Large Phantom
- Extremity (Breast) scanners – Small Phantom



ACR Large Phantom: 190 mm



ACR Small Phantom: 100 mm



# Establishing QC Action Limits

(Determined by the medical physicist. Must be as restrictive as ACR guidelines.)

1. Central frequency expressed in ppm (typically  $\pm 1.5$  ppm)  
(1.5 ppm @ 1.5T ~ 96 Hz or determined by the medical physicist)
2. Transmitter Gain or Attenuation (determined by medical physicist)
3. Geometric Accuracy ( $\pm 2$  mm)
4. High-Contrast Resolution (at least 1mm)
5. Low-Contrast Detectability (determined by medical physicist)
6. Artifacts (any artifacts should be noted and image saved)

**Common approach:** Determine mean and standard deviation (SD).

May need to use  $\pm 2SD$  depending upon the system.

# Annual Magnetic Field Homogeneity Testing

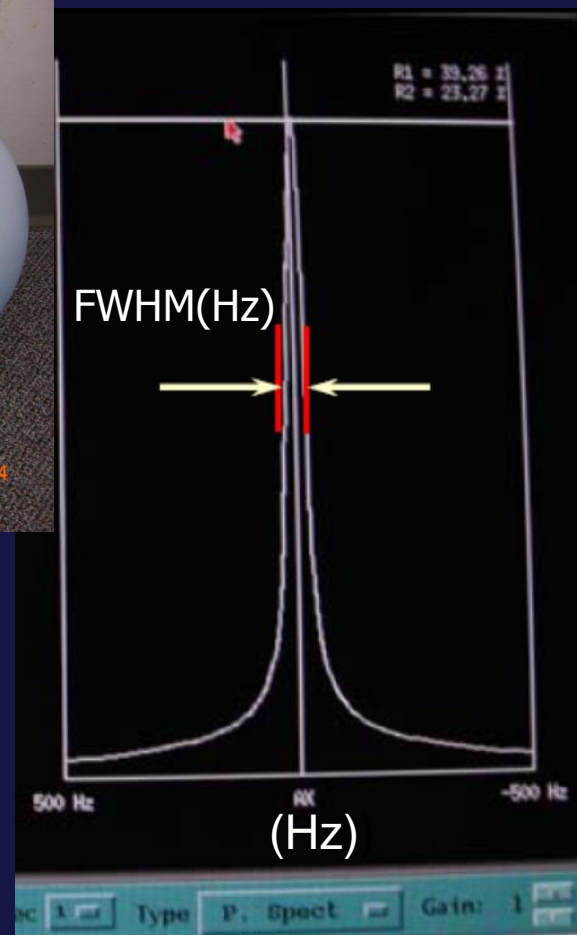
(Optional methods described in the revised manual.)

- **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** (Global sensitivity)
- (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

Spectral FWHM Method (**Same**)



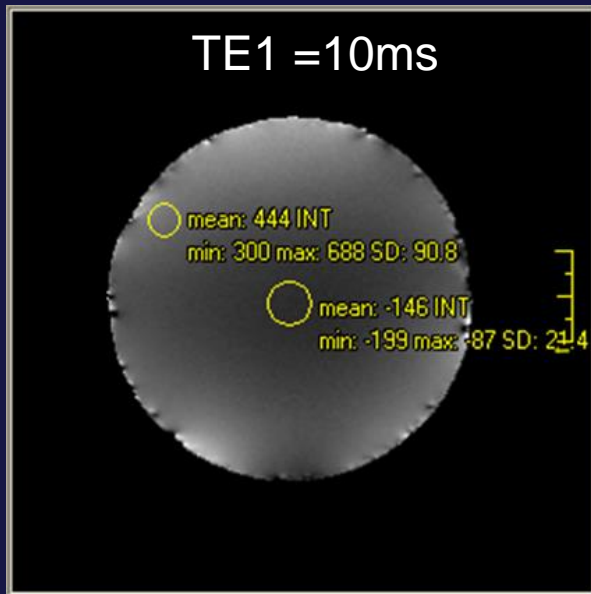
Spheres are provided by some vendors and should be used for the homogeneity tests. The sphere should be placed at the field isocenter.

The homogeneity should be specified for the largest diameter of the spherical volume (DSV) available.

$$\text{FWHM(ppm)} = \text{FWHM (Hz)} / 63.87 \text{ B}_0(\text{T})$$



# Phase-Difference Method



Phase Image 1



Phase Image 2



Difference Image

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

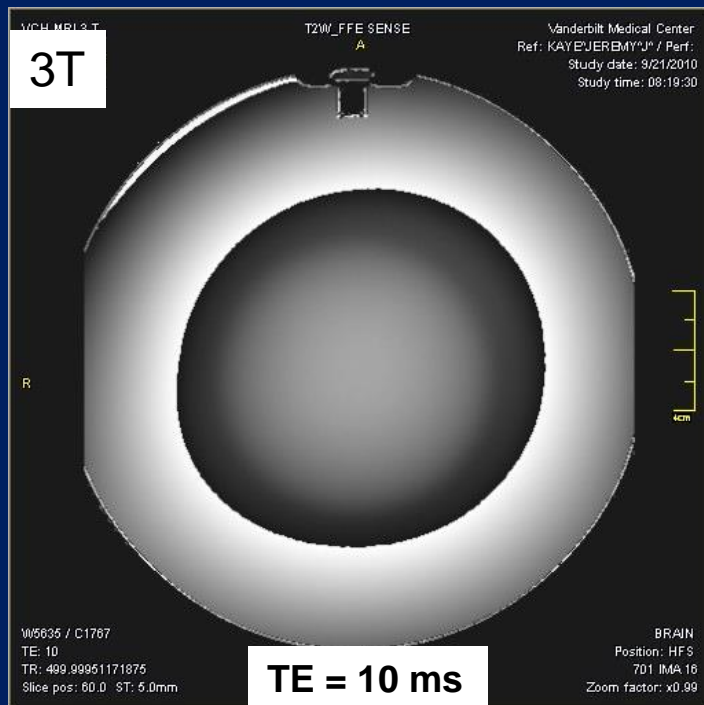
where the  $\Delta B_0$  is in mT,  $\Delta \phi$  is the phase difference in radians,  $\gamma$  is the gyromagnetic ratio and the TE values are in units of seconds. Use either a 3D Gradient Echo sequence or repeat the measurements for each orthogonal plane. The phase-difference method provides a spatial map of the field homogeneity within the chosen plane.

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

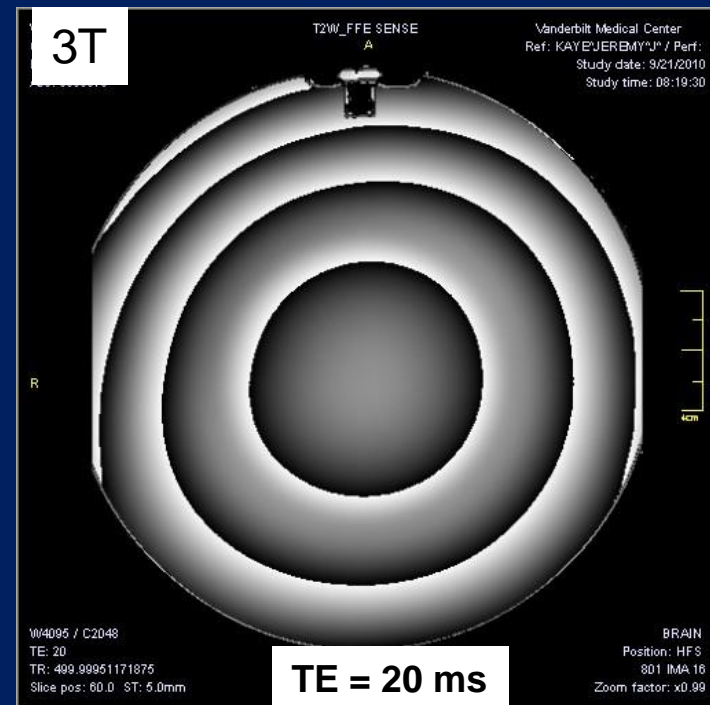
# Phase-Map Method

## (Revised Manual)

Gradient Echo Sequence:  $TE \sim 1/\text{resonance frequency (ppm)}$   
(e.g. 1 ppm @ 1.5T = 1/63 Hz = 15.6 ms)



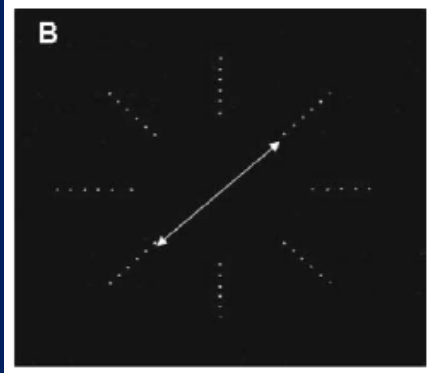
$TE = 10 \text{ ms} \sim 0.8 \text{ ppm/transition}$



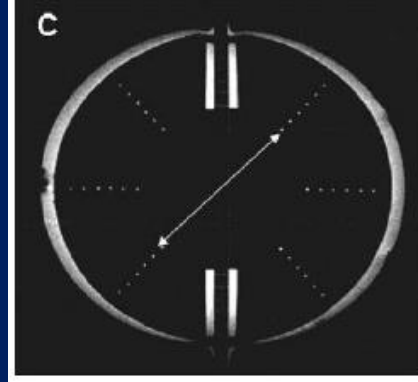
$TE = 20 \text{ ms} \sim 0.4 \text{ ppm/transition}$

The field homogeneity ( $\Delta B_0$ ) is determined by counting the number of transitions and then multiplying by the ppm/transition for the specific TE.

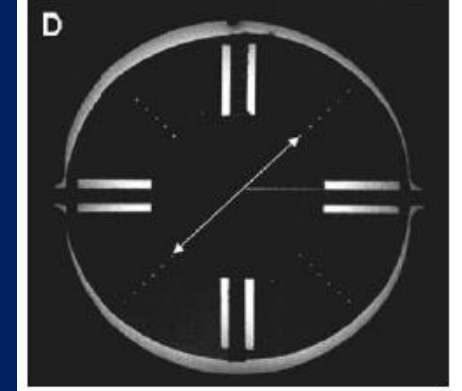
# Bandwidth-Difference Method\* (Revised Manual)



Axial

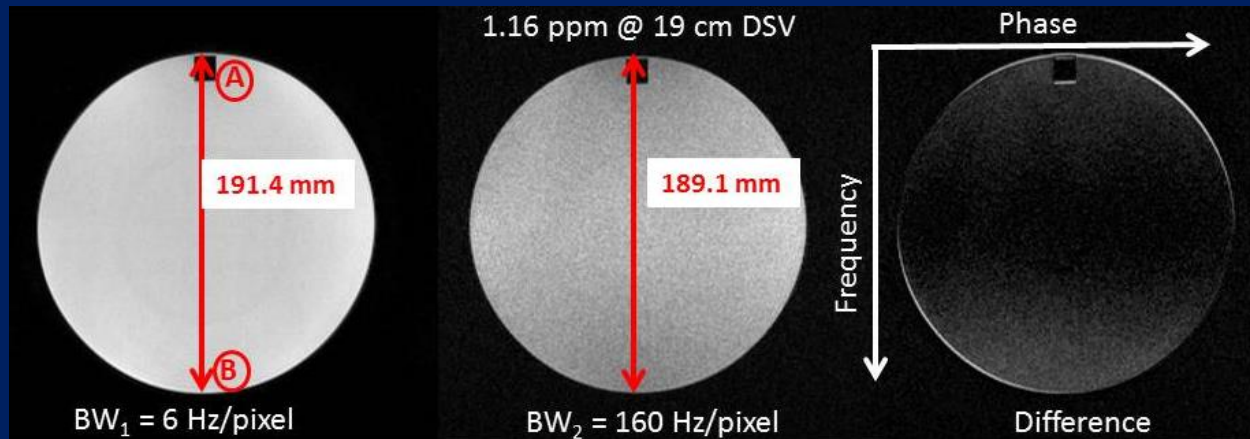


Sagittal



Coronal

$$H_B(\text{ppm}) = \frac{BW_1 \cdot BW_2 \cdot (x'_1 - x'_2)}{\gamma \cdot B_0 \cdot \text{FOV}_x (BW_2 - BW_1)}$$



**Note:** The BW-difference method is sensitive to homogeneity in the frequency-encode direction only and thus should be repeated for all three orthogonal axes at largest DSV.

\*Chen, et al Med. Phys. 33 (11), 2006.

# The ACR MRI accreditation program requires that field homogeneity be assessed:

20% 1. As part of the weekly QA

20% 2. When a new coil is purchased

20% 3. Only at the time of installation

20% 4. At each annual performance testing

20% 5. By the vendor's service engineer

The ACR MRI accreditation program requires that field homogeneity be assessed:

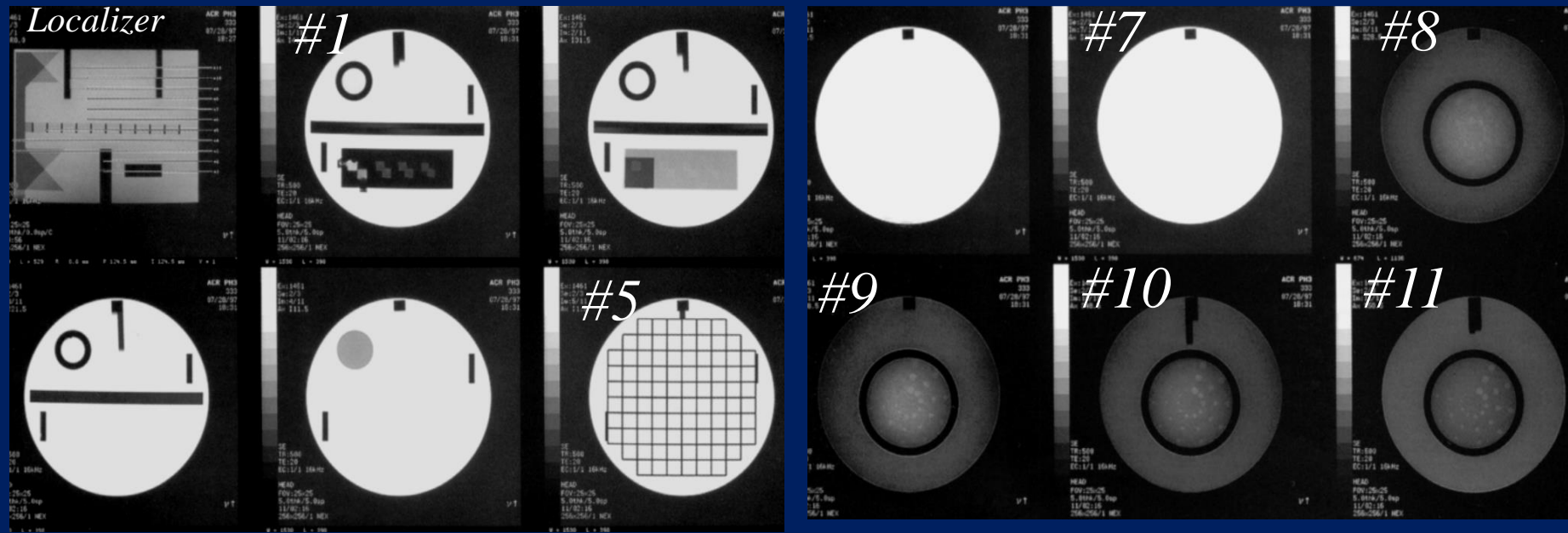
1. As part of the weekly QA
2. When a new coil is purchased
3. Only at the time of installation
4. At each annual performance testing
5. By the vendor's service engineer

Reference: ACR MRI Accreditation Requirements

<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)**

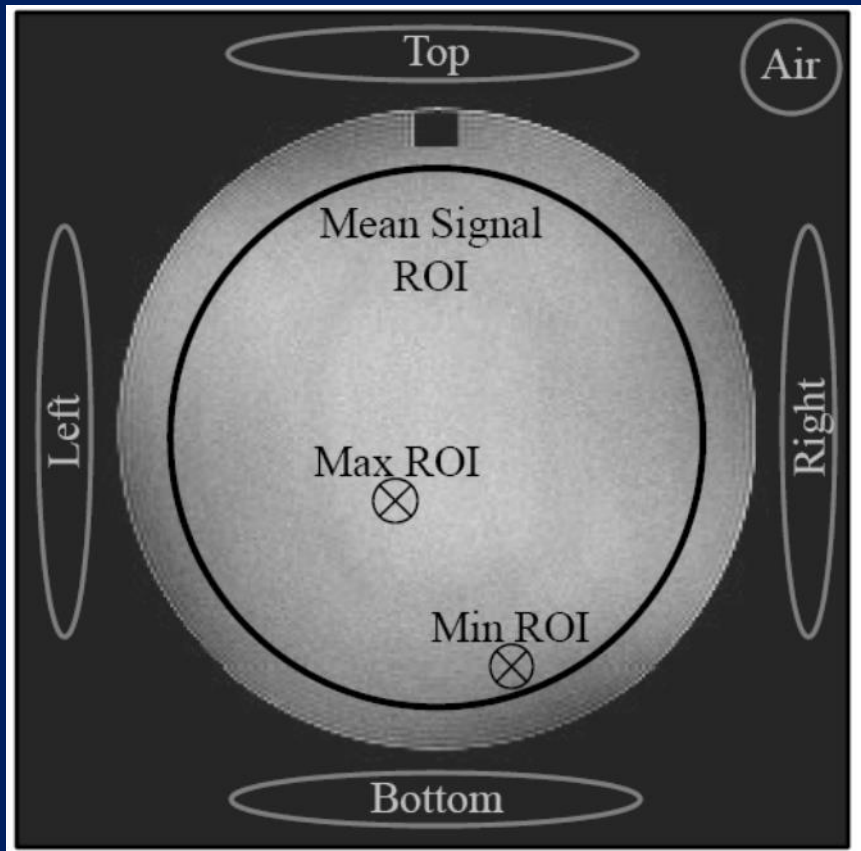
**#7) Percent image uniformity (PIU), Percent signal ghosting (PSG)**

**#8-11) Low contrast object detectability (LCD), and slice position (in #11)**

*Images courtesy of E.F. Jackson, PhD*

# Volume Coil SNR (two SNR methods in revised manual)

(Two SNR methods in revised manual: Single-image or Image-difference)



Assess for all coils used clinically with a uniform phantom.

## 1. Single-Image Methods

**Note:** Intensity correction algorithms should be off

a. ACR 2004 Original:  $(\text{SNR} = \text{Mean Signal} / \sigma_{\text{air}})$

b. NEMA Method 4:  $(\text{SNR} = 0.655 \times \text{Mean} / \sigma_{\text{air}})$

## 2. Image-Difference Method

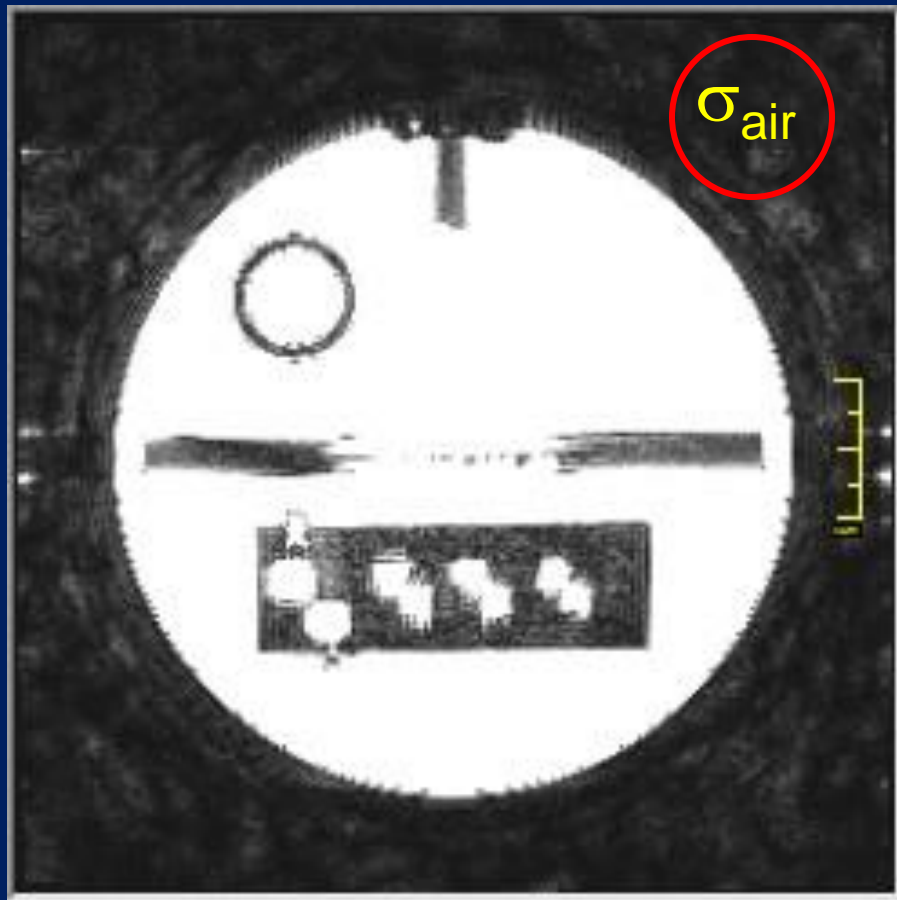
**Image-Difference Method: NEMA Method 1**

NEMA MS 1-2008: Determination of Signal-to-Noise Ratio in Diagnostic Magnetic Resonance Images (Method 4)

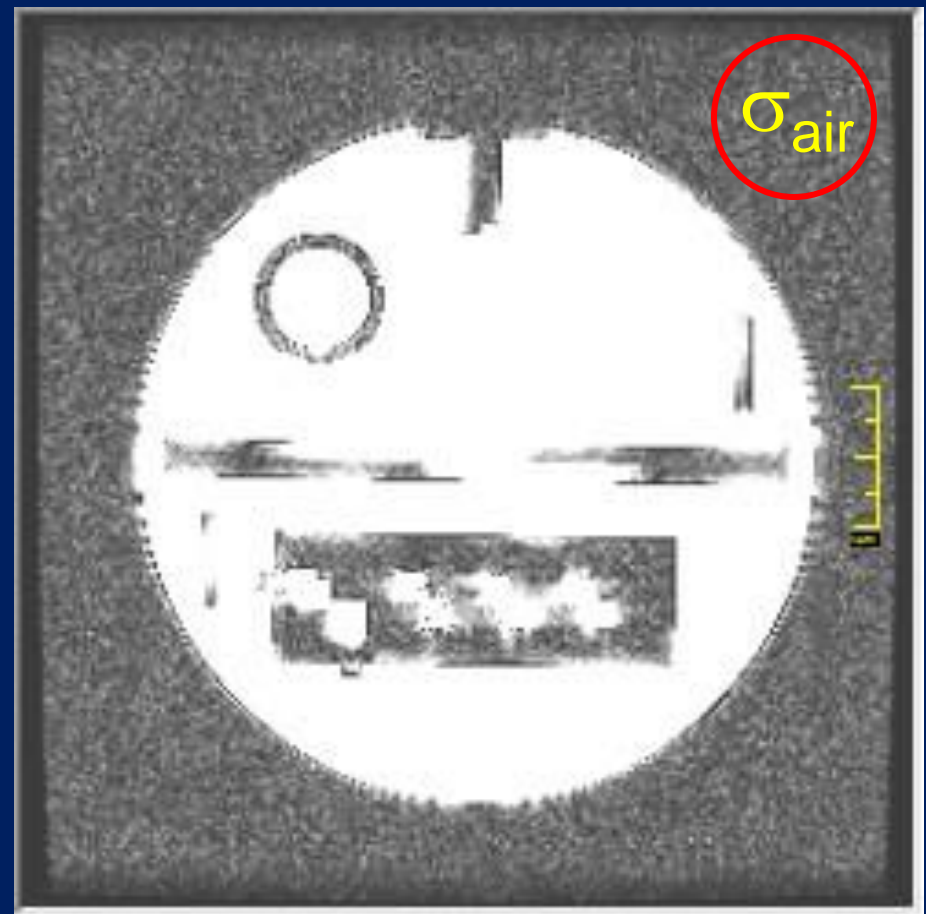
Note: No background subtraction and NEMA (4)  $\times 0.655$  for Rician noise correction.



For Single-image methods, image intensity correction should be off e.g. SCIC, CLEAR and PURE. The intensity correction algorithm will significantly affect the background noise ( $\sigma_{\text{air}}$ ) estimate and thus the calculated SNR.

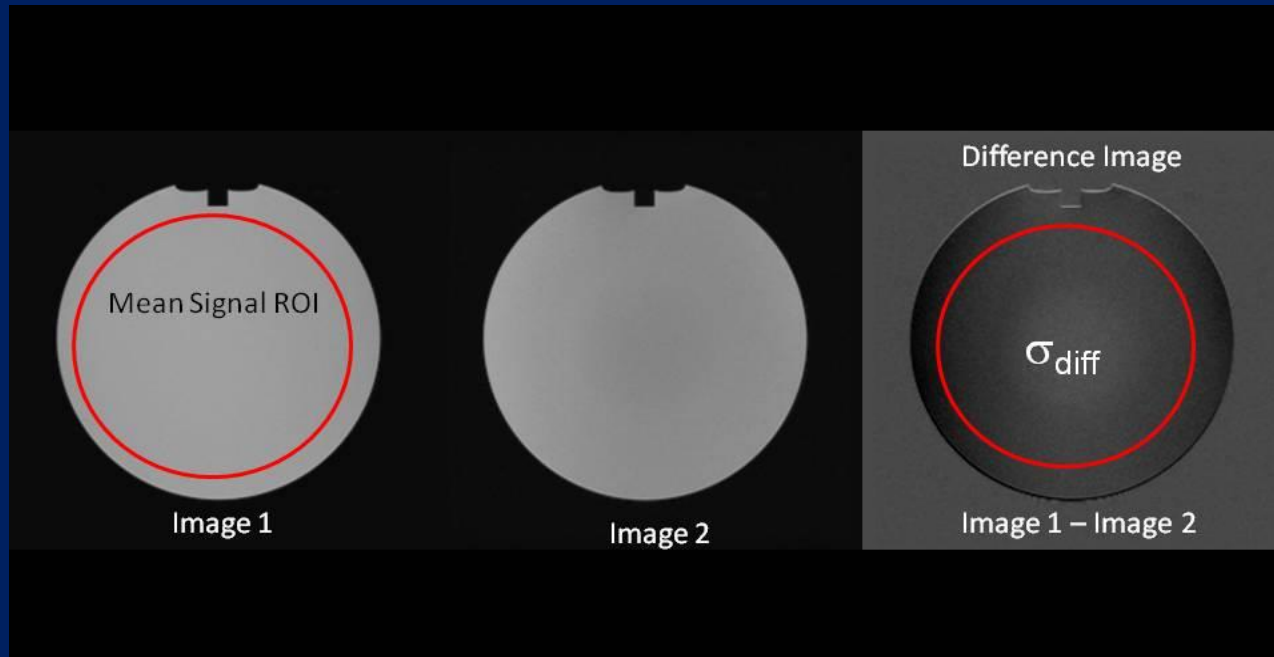


With intensity correction



Without intensity correction

# Image-Difference Method (NEMA Method 1\*)



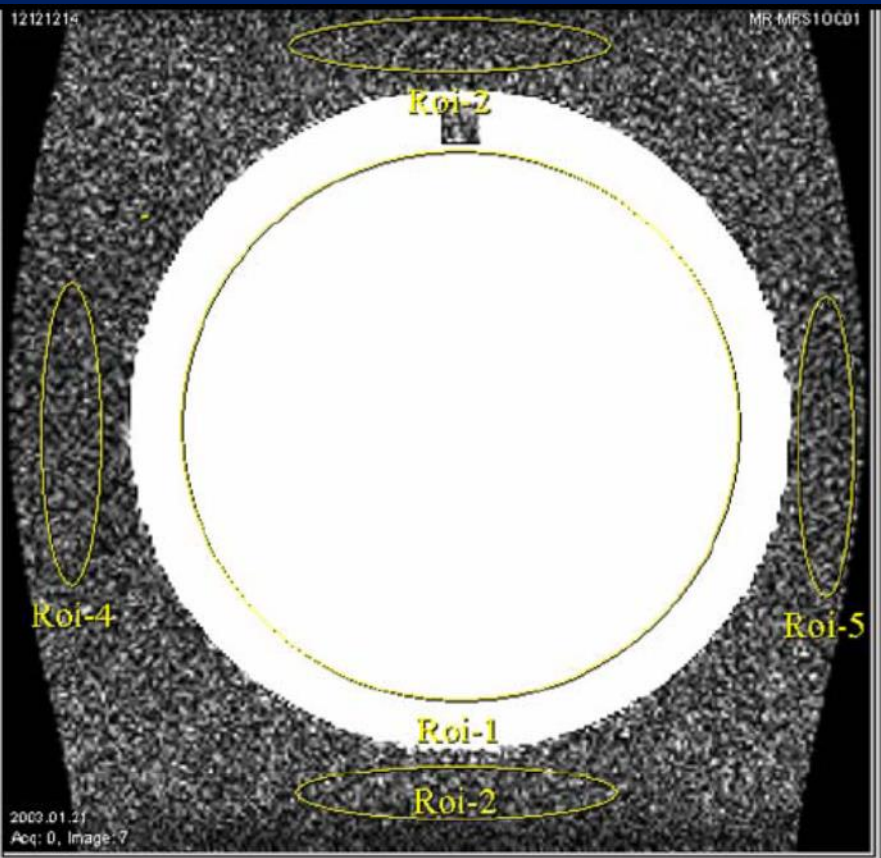
$$SNR = \sqrt{2} \frac{\text{Mean Signal}}{\sigma_{diff}}$$

$\sqrt{2}$  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)

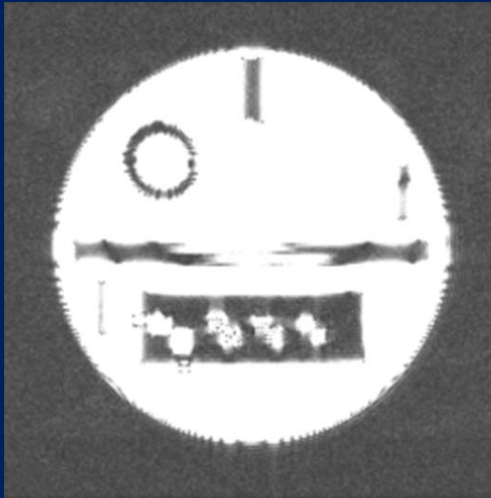
# Gradient Non-linearity Correction Effect on PSG



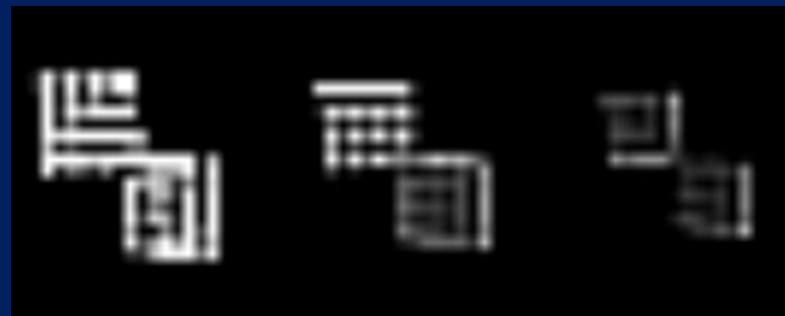
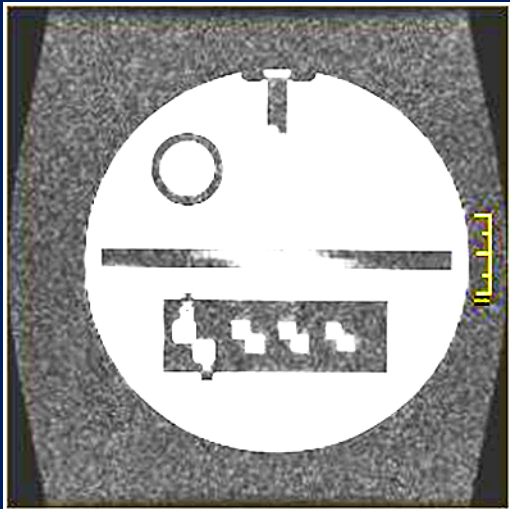
Window and level to make sure ROIs are in the background noise.

(Warping of image space due to gradient nonlinearity corrections may affect ROI location.)

# Gradient Distortion Correction Effect on Spatial Resolution



Without Correction

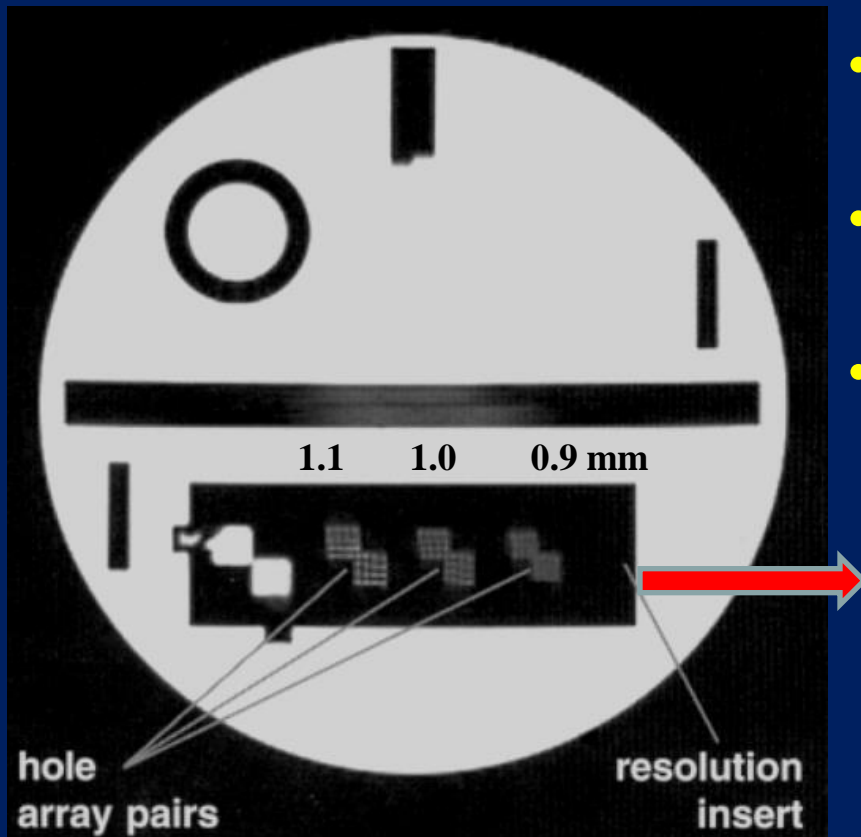


With Correction

# High Contrast Spatial Resolution

ACR T1 and T2

- 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



Slice 1

44

Criterion: 1.0 mm

When measuring SNR in multi-element volume coils, it is recommended that:

20% 1. Only the ACR phantom be used

20% 2. Intensity-correction algorithms be used

20% 3. Largest available image matrix be used

20% 4. Be performed by the service engineer

20% 5. Each individual element be tested

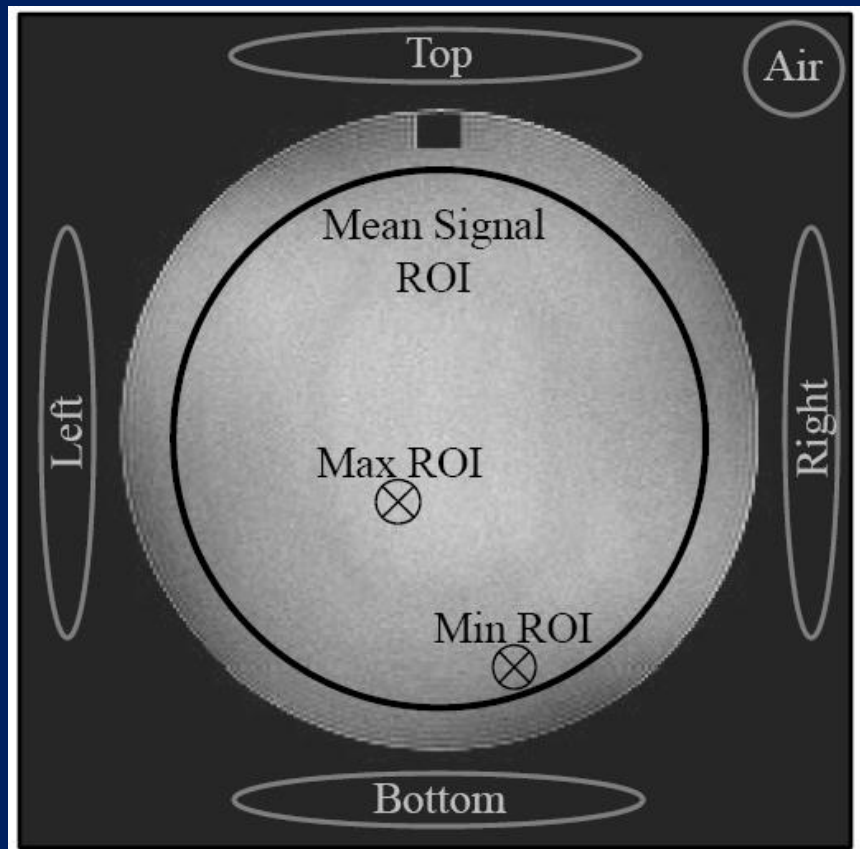


When measuring SNR in multi-element volume coils, it is recommended that:

1. Only the ACR phantom be used
2. Intensity-correction algorithms be used
3. Largest available image matrix be used
4. Be performed by the service engineer
5. Each individual element be tested

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

# Volume Coil PIU and PSG : (2014 ACR Manual)



Percent Image Uniformity: PIU (same)

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

Percent Signal Ghosting: PSG (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.

# ACR Small Phantom

## (Extremity Systems)

Sag localizer: Geometric accuracy

#1) Slice thickness and position, geometric accuracy, high contrast resolution

#3) Geometric accuracy

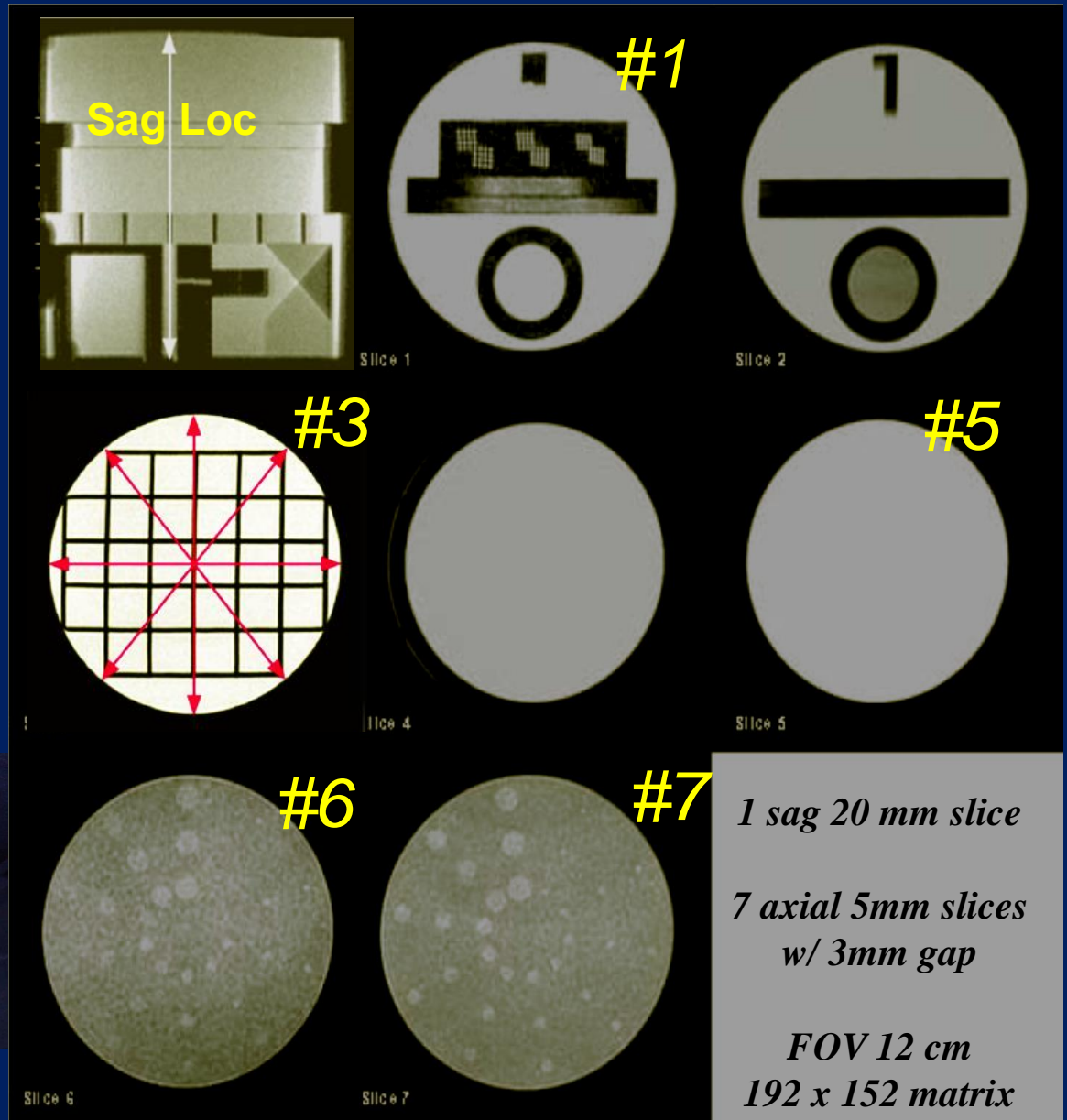
#5) PIU, ghosting (PSG)

#6-7) LCD



### Five Sequences

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



# ACR Guidelines for Phantom Scans

## Large Phantom **ACR Limits: Unchanged**

(FOV = 25 cm, 256X256)

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

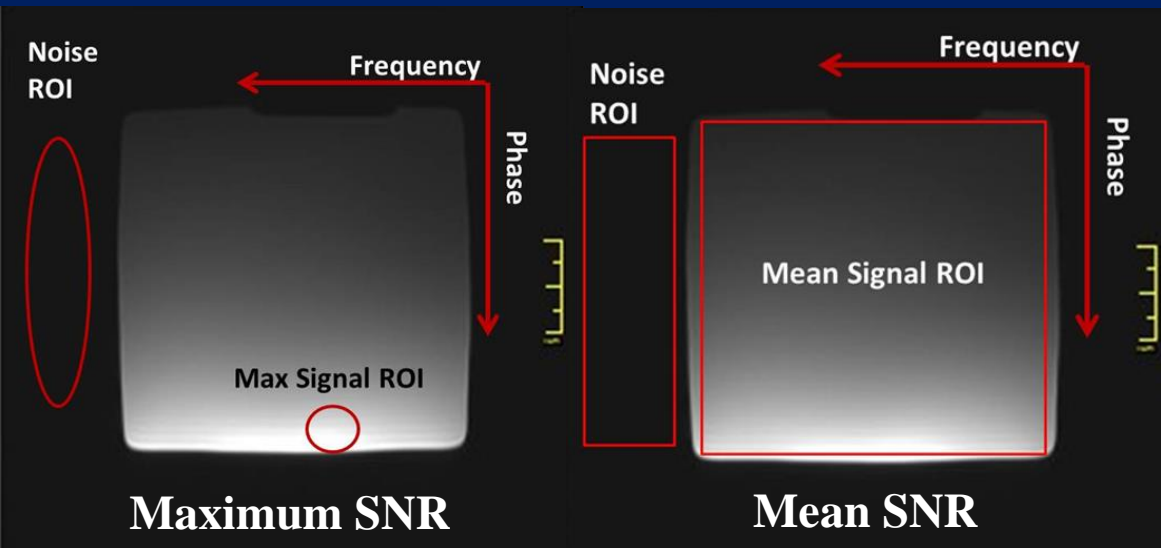
## Small Phantom **ACR Limits: Unchanged**

(FOV = 12 cm, 152X192)

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

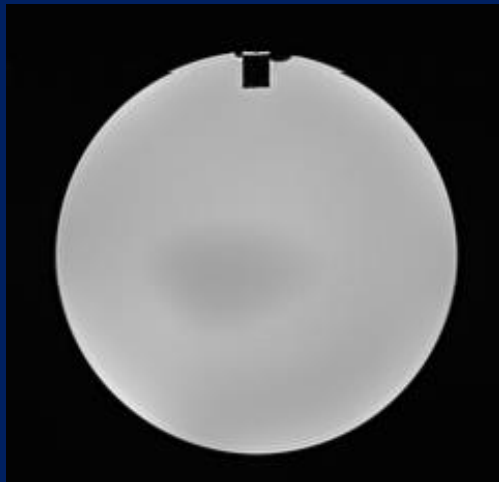
# Surface Coil SNR Measurements: **Changes**

Original manual recommendation was to use phantom geometry that best matched the coil and to measure the **Maximum SNR**. In order to improve year-to-year reproducibility, recommendation is to measure the **Mean SNR** and to use the largest ROI's possible for both signal and background.

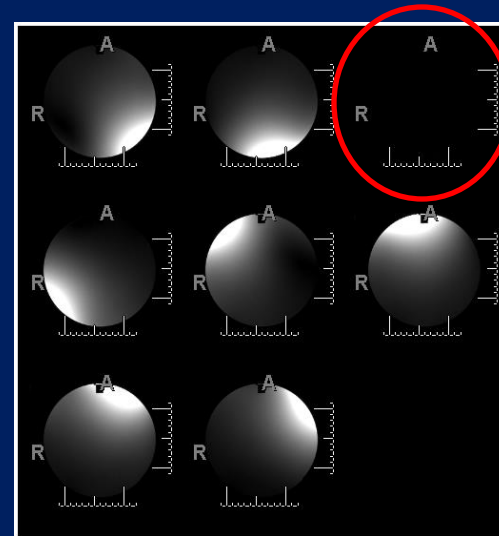


# Testing Coil Arrays

The revised ACR MRI Manual recommends that if possible the images from each coil element be reconstructed and evaluated individually to check for malfunctioning 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



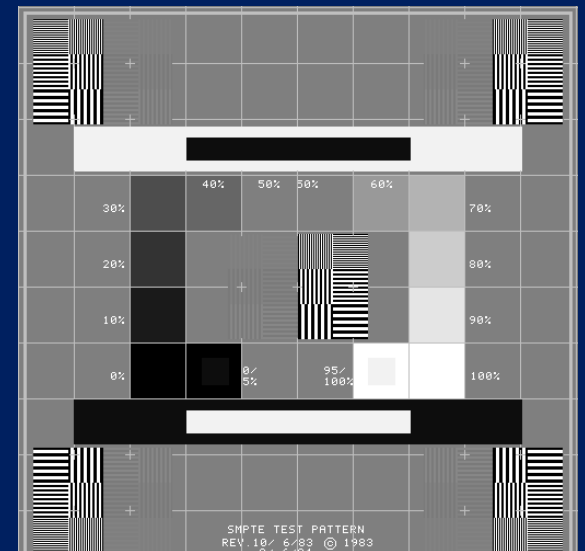
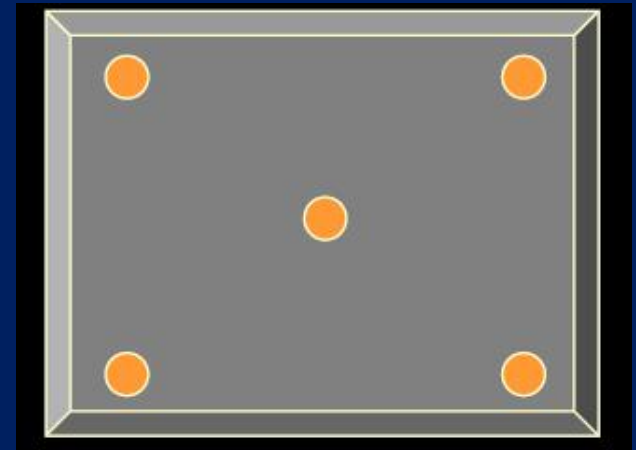
# Soft Copy Displays (no changes)

## 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):  $> 90 \text{ Cd/m}^2$
2. Min luminance:  $< 1.2 \text{ Cd/m}^2$
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  $\pm 5 \text{ mm}$



# **ACR Medical Physicist's Site Safety Assessment (Checklist)**

**(All new section)**

- **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**



# Revised Requirements for Diagnostic Imaging Services

## Joint Commission MRI Safety Performance Standards

### Standard EC.02.01.01

The [critical access] hospital manages safety and security risks.

#### Elements of Performance for EC.02.01.01

**A 14.** For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: The [critical access] hospital manages safety risks in the MRI environment associated with the following:

- Patients who may experience claustrophobia, anxiety, or emotional distress
- Patients who may require urgent or emergent medical care
- Patients with medical implants, devices, or imbedded foreign objects (such as shrapnel)
- Ferromagnetic objects entering the MRI environment
- Acoustic noise

**A 16.** © For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: The [critical access] hospital manages safety risks by doing the following:

- Restricting access of everyone not trained in MRI safety or screened by MRI-trained staff from the scanner room and the area that immediately precedes the entrance to the MRI scanner room.
- Making sure that these restricted areas are controlled by and under the direct supervision of MRI-trained staff.
- Posting signage at the entrance to the MRI scanner room that conveys that potentially dangerous magnetic fields are present in the room. Signage should also indicate that the magnet is always on except in cases where the MRI unit, by its design, can have its magnetic field routinely turned on and off by the operator.

**A 25.** © For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: The [critical access] hospital verifies and documents that technologists who perform MRI examinations participate in ongoing education that includes annual training on safe MRI practices in the MRI environment, including the following:

- Patient screening criteria that address ferromagnetic items, medical implants and devices, and risk for nephrogenic systemic fibrosis (NSF)
- Proper patient positioning activities to avoid burns
- Equipment and supplies that have been determined to be acceptable for use in the MRI environment (MR safe or MR conditional)\*
- MRI safety response procedures for patients who require urgent or emergent medical care
- MRI equipment emergency shutdown procedures
- Patient hearing protection
- Management of patients with claustrophobia, anxiety, or emotional distress

*\* Terminology for defining the safety of items in the magnetic resonance environment is provided in ASTM F2503 Standard Practice for Marking Medical Devices and Other Items for Safety in the Magnetic Resonance Environment (<http://www.astm.org>).*

#### Elements of Performance for PI.01.01.01

**A 46.** For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: The [critical access] hospital collects data on patient burns that occur during MRI exams.

**A 47.** For [critical access] hospitals that provide magnetic resonance imaging (MRI) services: The [critical access] hospital collects data on the following:

- Incidents where ferromagnetic items entered the MRI scanner room
- Injuries resulting from the presence of ferromagnetic items in the MRI scanner room

As part of the annual performance testing, the medical physicist is expected to perform all of the following **except**:

20% 1. Site safety assessment

20% 2. Repeat of weekly QA tests

20% 3. Static-field gradient measurement

20% 4. Magnetic field homogeneity test

20% 5. SNR for all clinical coils

As part of the annual equipment performance testing, the medical physicist is expected to perform all of the following except:

1. Site safety assessment
2. Repeat of weekly QA tests
3. Static-field gradient measurement
4. Magnetic field homogeneity test
5. SNR for all clinical coils

Reference: ACR MRI Accreditation Requirements

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

# Conclusion and Comments

- **The revised ACR MRI Quality Control Manual has relatively minor changes from the 2004 version. Specific tests are basically the same but with more options and better descriptions.**
- **There is a increased emphasis on MRI safety and infection control to minimize patient risk.**
- **An attempt was made to embrace NEMA standards, Joint Commission recommendations and AAPM Report 100.**
- **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.**