From the Trenches: Implementing the Changes of the New QA MR Manual

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Outline

Annual ACR Testing Overview

Standard Testing Details

Magnetic Field Homogeneity

SNR Coil Testing

MR Site Safety

Note: discussion only covers use of large phantom.

Caveat: Currently, I work solely with GE, Philips machines.

What is the point of testing?

Quality Control – testing to ensure that images are satisfactory.

Satisfactory = **Acceptable for clinical usage/diagnosis**.

"Meet a standard." ≠ "Excellence in quality."

Also, wish to maintain quality over time.

We should all strive towards excellence, but …

we surely don't want images that are incapable of showing pathology.

Ultimately, want to detect what is wrong <u>before</u> we get to that stage, and we want to ensure that problems get <u>fixed</u>.

Annual ACR Testing (pre-2015)

Weekly QC (technologist):

Table Positioning, Setup and Scanning
Center (Central) Frequency
Transmitter Gain or Attenuation
Geometric Accuracy
High-Contrast Spatial
Low-Contrast Detectability
Artifact Evaluation
Hardcopy (Film) QC (if applicable)
Visual Checklist

Annual QC (MP):

Percent Signal Ghosting (PSG) Image Intensity Uniformity (PIU)
Magnetic Field Homogeneity
Slice Position Accuracy
Slice Thickness Accuracy
Radiofrequency Coil Checks (SNR for all coils used clinically)
Soft Copy (Monitor) QC (Luminance, uniformity and SMTE)

Joint Commission Requirement

Revised Requirements for Diagnostic Imaging Services

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.*

Annual ACR Testing (2015+)

Repeat of weekly stuff → use the site head coil.

E.g., we scan more than 50% of brain patients using our 32-channel head coil, so we use that.

If you can't test it, then why are you using it?

	Tests	Weekly QC(tech)	Annual Eval(MP)
1	Setup and Table Position Accuracy	X	X
2	Center Frequency	X	X
3	Transmitter Gain or Attenuation	X	X
4	*Geometric Accuracy Measurements*	X	X
5	*High-Contrast Spatial Resolution*	X	X
6	*Low-Contrast Detectability*	X	X
7	Artifact Evaluation	X	X
8	Film Printer Quality Control (if applicable)	X	X
9	Visual Checklist	X	X
10	Magnetic Field Homogeneity		X
11	*Slice-Position Accuracy*		X
12	*Slice-Thickness Accuracy*		X
13	Radiofrequency Coil Checks		X
	a. SNR		X
	b. Percent Image Uniformity (PIU)		X
	c. Percent Signal Ghosting (PSG)		X
14	Soft-Copy (Monitor) Quality Control		X
15	MR Safety Program Assessment		X

Beginning of Manual

ANNUAL MRI SYSTEM PERFORMANCE EVALUATION

The annual MRI system performance evaluation must include the previously described technologist QC measurements, scanning and analyzing the ACR MRI phantom as submitted for accreditation, and the measurements described below and listed in Table 2. The method for performing these measurements may vary according to the needs of the facility and the preference of the medical physicist/MRI scientist. If the medical physicist/MR scientist is using other than ACR-specified methods, the alternative methods should be fully documented for the facility's record. For some of these tests, the ACR MRI accreditation phantom may not be the most appropriate tool. In addition, many of these values will be system-specific, and baseline values will have to be determined when the system is commissioned or when the qualified medical physicist/MRI scientist first undertakes a performance analysis. In the written performance report, the medical physicist/MRI scientist should specifically include the comparison of current test results with the baseline values and report trends when appropriate. At the time of these tests, the qualified medical physicist/MRI scientist also reviews the weekly QC records, service logs, and safety policies and procedures, and recommends changes in QC program procedures indicated by these data.

ACR Large Phantom Protocol

Sagittal Localizer: 1 slices, SE, TR=200ms, TE=20ms, FOV=25cm, slice thickness=2mm, matrix=256x256, NEX=1

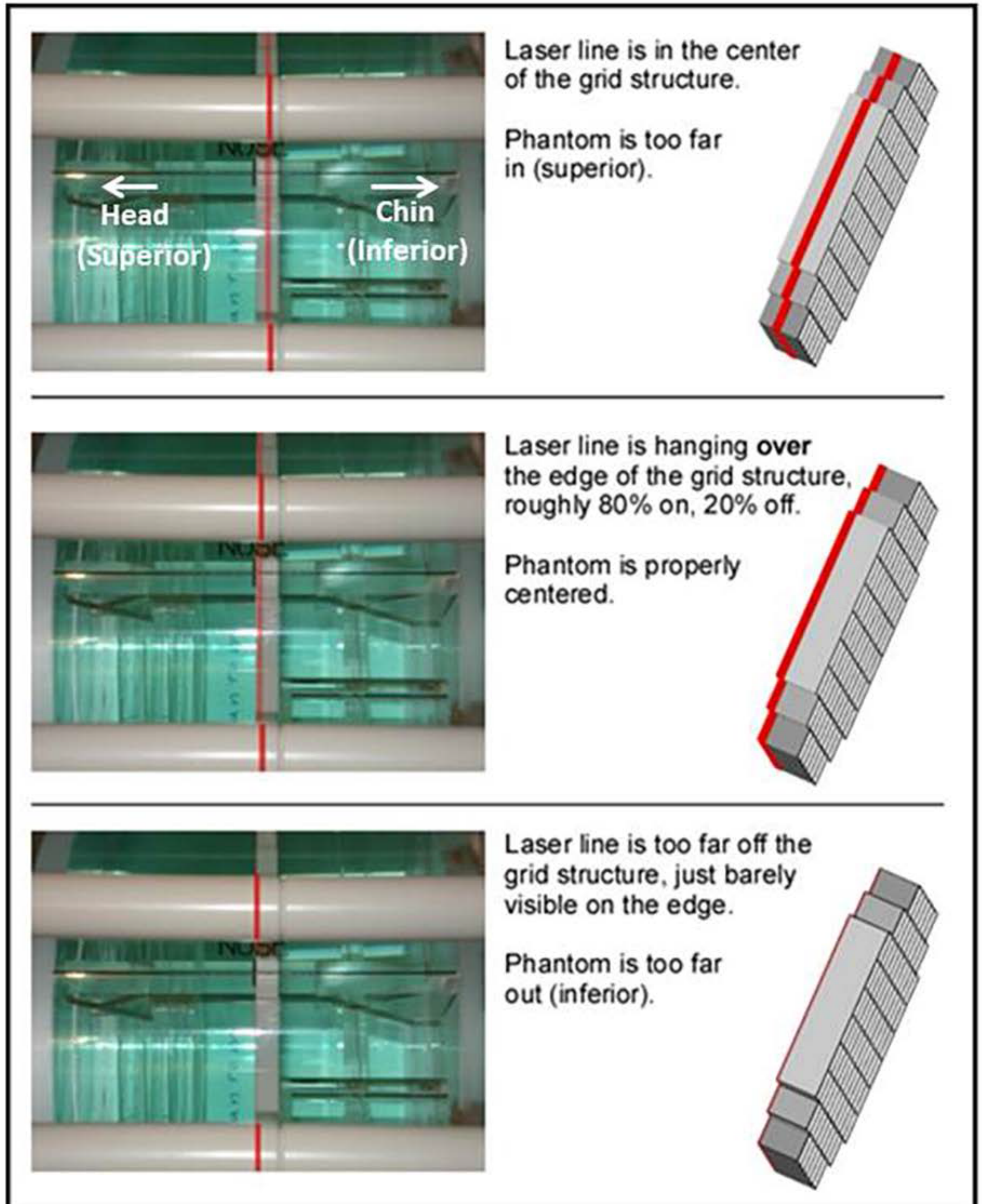
ACR T1: axial, 11 slices, SE, TR=500ms, TE=20ms, FOV=25cm, slice thickness=5mm, slice gap=5mm, matrix=256x256, NEX=1

ACR Dual-Echo T2: axial, 11 slices, GRE, TR=500ms, TE=20/80ms, FOV=25cm, slice thickness=5mm, slice gap=5mm, matrix=256x256, NEX=1

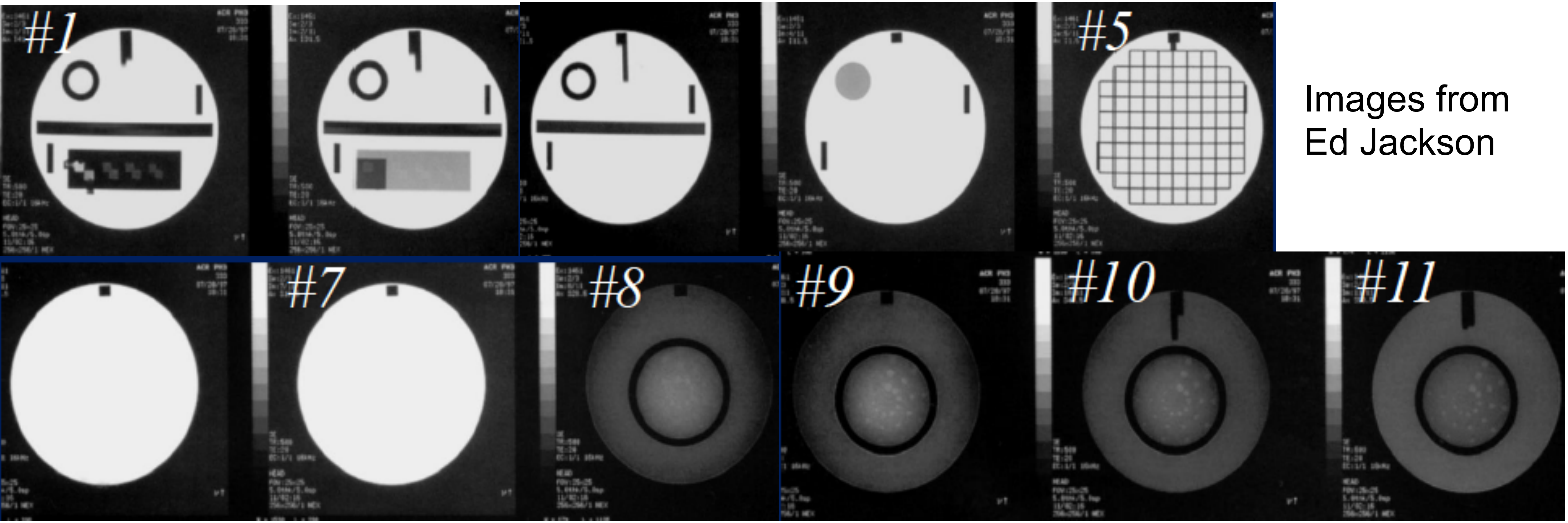
Placement of the Phantom

If you spend a decent amount of time getting it straight, then sagittal and axial prescriptions work well.

Scan, then check low contrast detectability quickly to see if you're spot on.



ACR Large Phantom and Testing



Images from
Ed Jackson

Function of slice:

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

#5) Geometric accuracy (x,y)

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

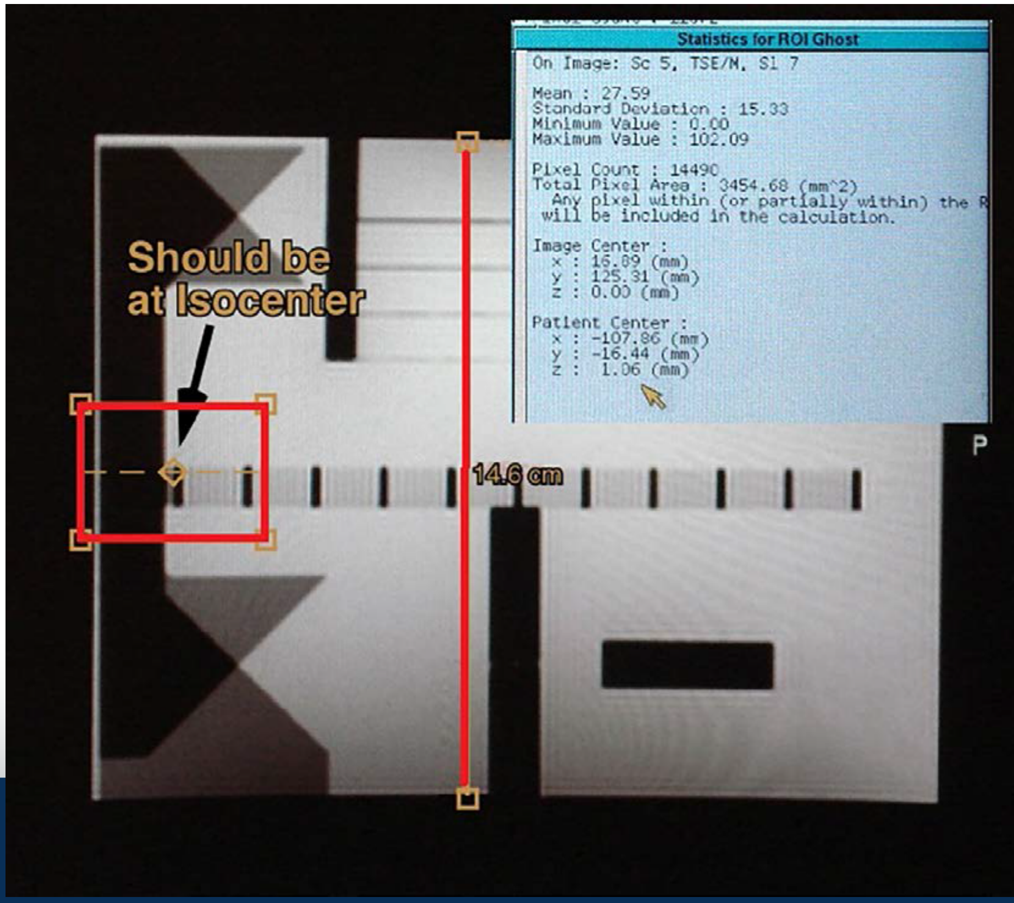
#8-11) Low contrast object detectability (LCD),

#11) Slice position

Table Positioning Test

Method:

- Place the phantom in the head coil as per weekly testing (landmark superior grid edge). Send to isocenter, and verify alignment with three-plane localizer.
- Perform the ACR sagittal localizer.
- With a cursor on the scanner, confirm that superior edge of grid should be at S0.0±5.0.



Issues: laser alignment,

phantom alignment.

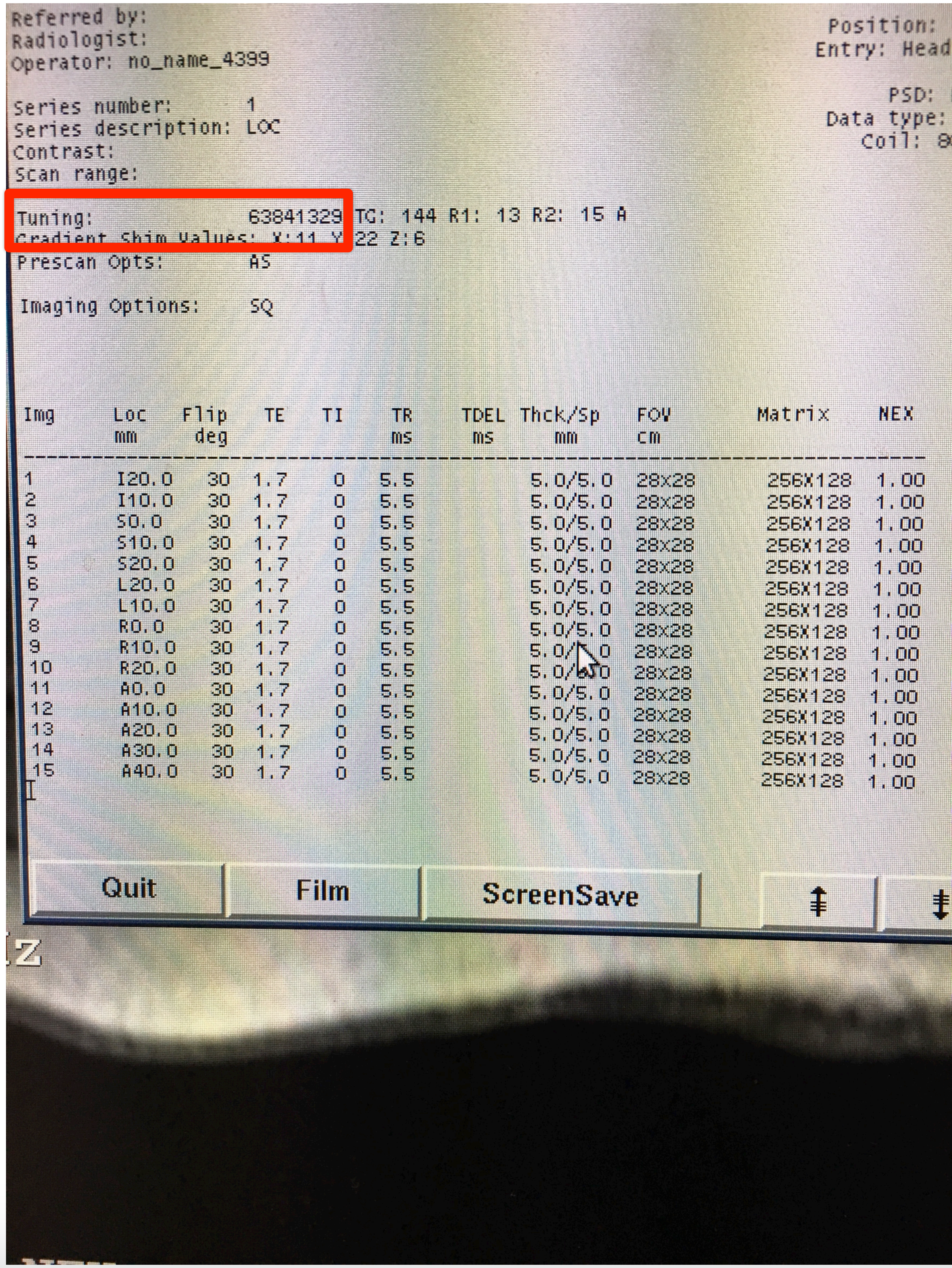
Center Frequency

Method: set up T1 scan.

Prescan will determine center frequency.

Check vs. action limit.

If there are issues, make sure to confirm with weekly QC (mandatory anyway…but this is your first check).



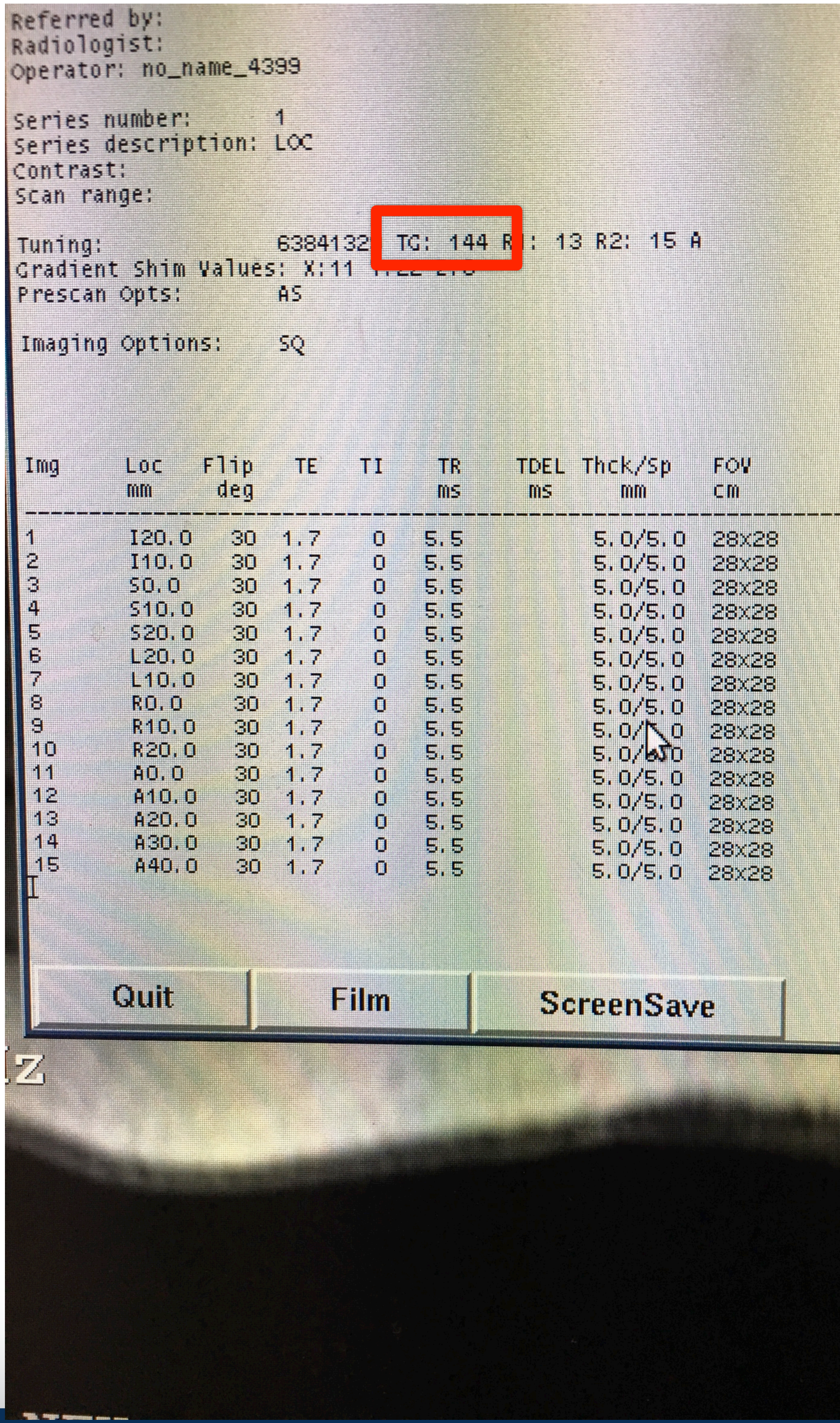
Transmitter Attenuation

Same process as center frequency.

Implications:

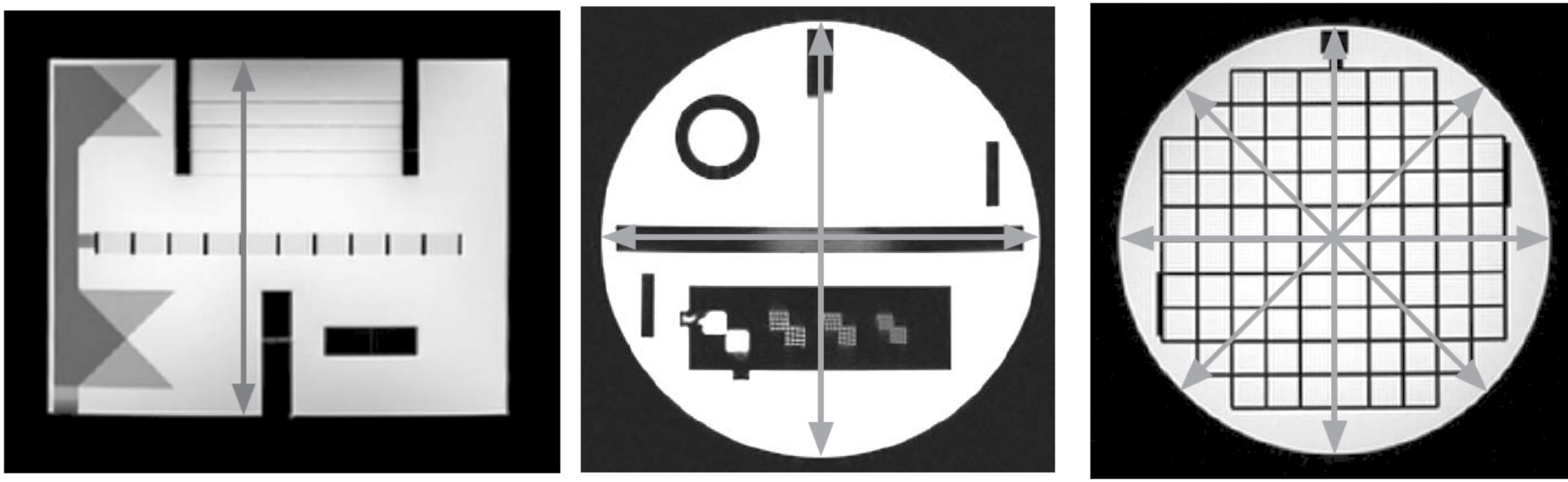
Transmitter gain – body coil issues, receiver chain issues.

Newer scanners (split transmit): need to record info for both channels.



Geometric Accuracy

Use both the sagittal localizer and ACR T1 (slice 1,5).



- Adjust level to ½ of mean signal.
- Adjust window to mean signal value.

Pass: End-to-end: 148±2mm (localizer); Diameter: 190±2mm.

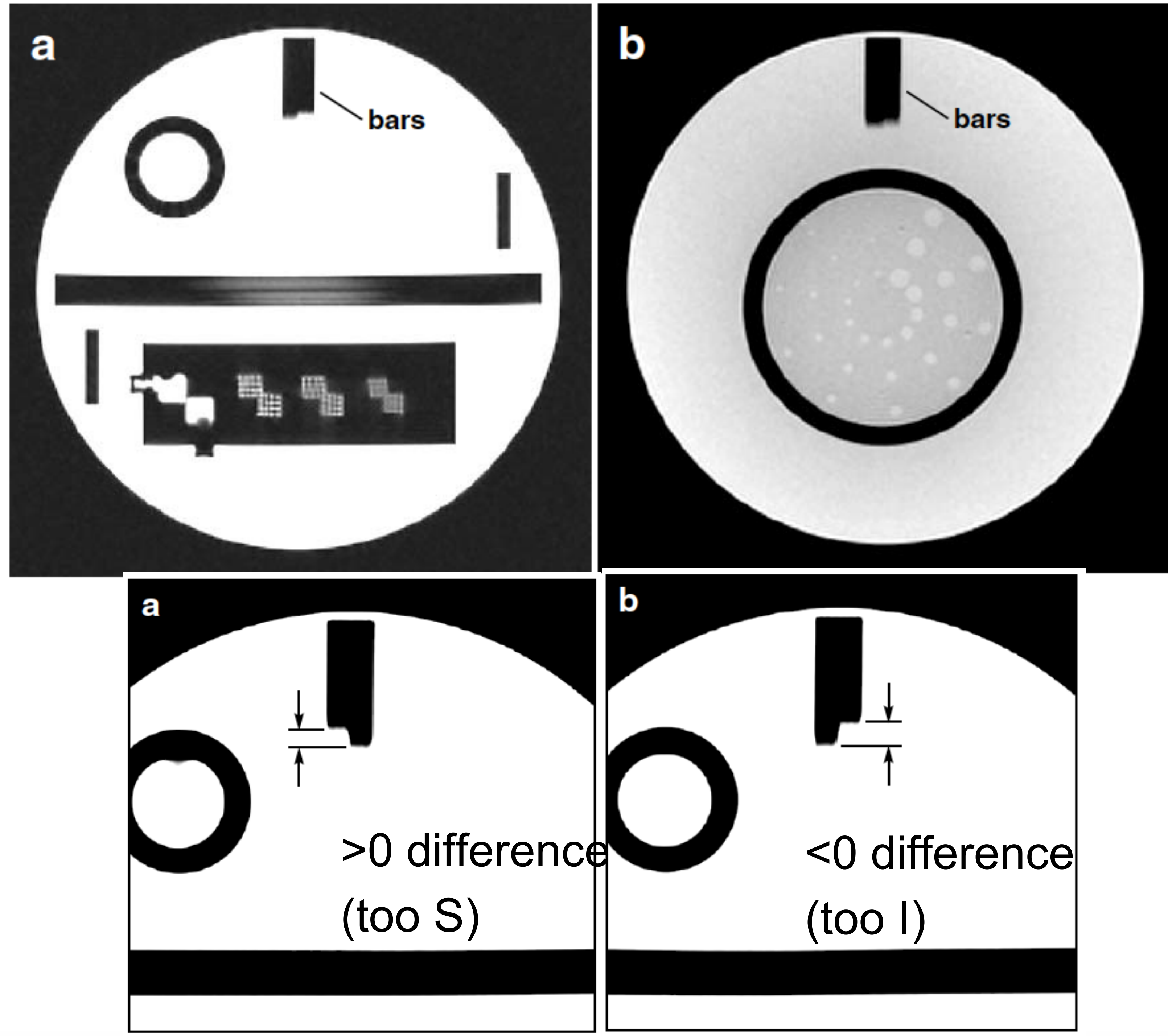
Failures: gradient issues, poor positioning, small BW

Slice-Position Accuracy

Method (ACR T1, T2)

Slices 1 & 11

- Magnify to see better.
- Use minimal window, level set ~ half brightness of water.
- Measure length of left and right bars.



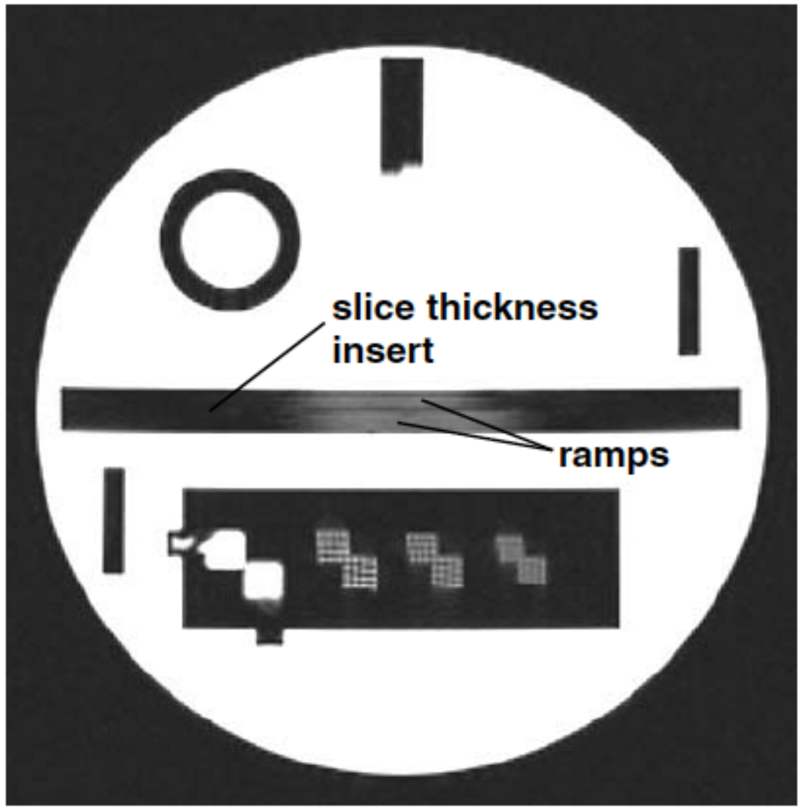
Pass: difference ≤ 5mm

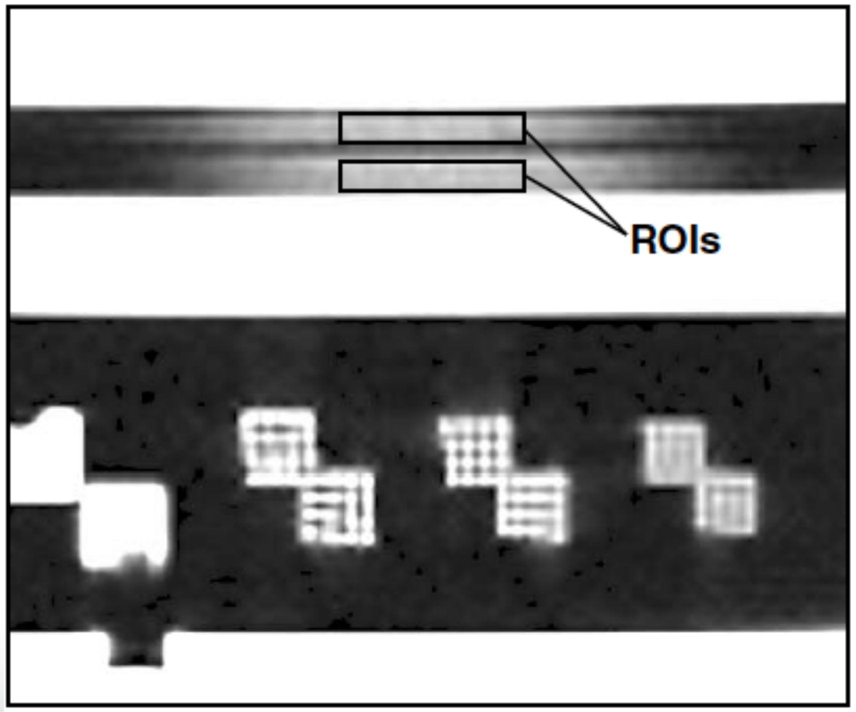
Failure: alignment issues (try again), table motion issues, gradient non-linearity.

Slice-Thickness Accuracy

Method (ACR T1 & T2)

- Magnify slice 1.
- Lower level to see ramps well.
- Put two ROIs in ramps and calculate means, and average.
- Set level to ½ of average, and window to minimum.





Slice-Thickness Accuracy

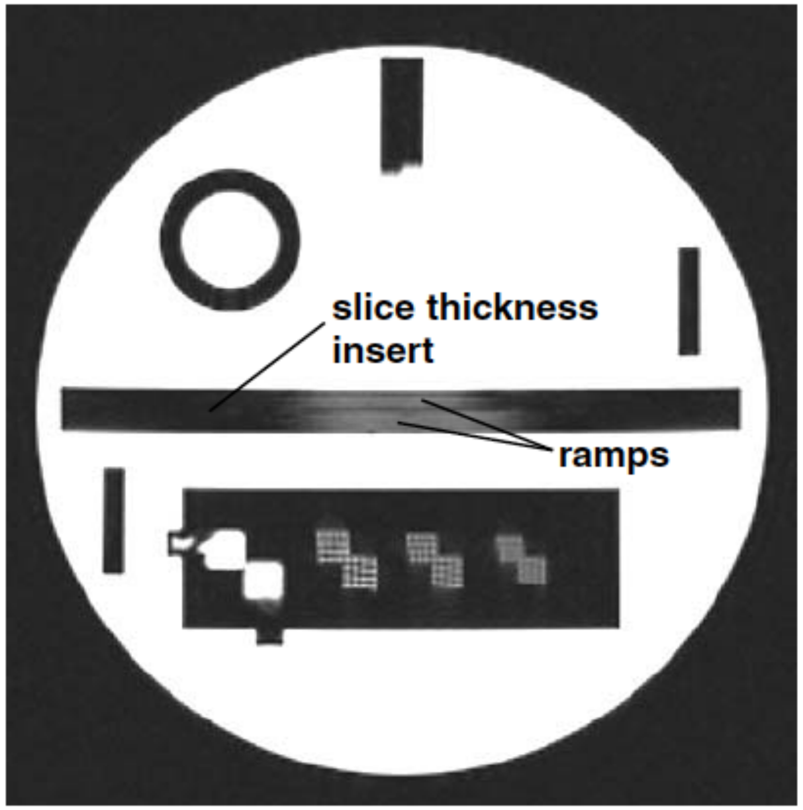
Method (ACR T1 & T2)

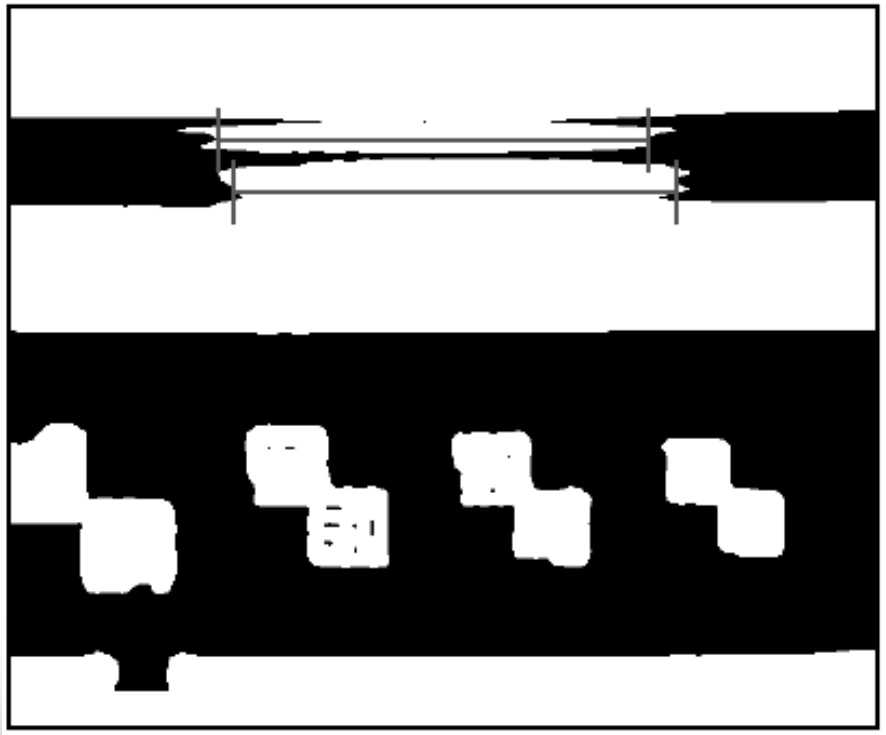
- Measure the length of the ramps (do your best for jagged edges).

$$slice\_thickness = \left[\frac{0.2 \times (top \times btm)}{(top + btm)} \right]$$

Pass: =5.0±0.7mm

Failure: RF electronics issues (distorted pulses, coil), gradient calibration issues.



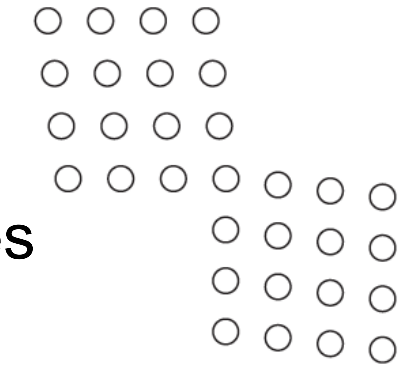


High-Contrast Spatial Resolution

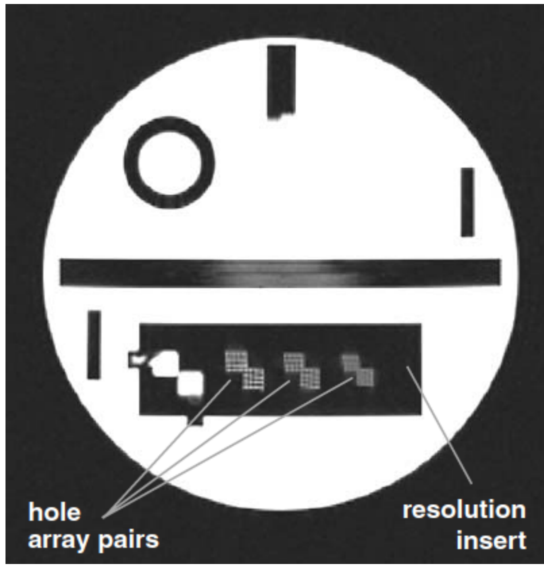
Slice #1

Pass: Any row (UL) or column (LR) with four distinctive holes is good. Need 1mm.

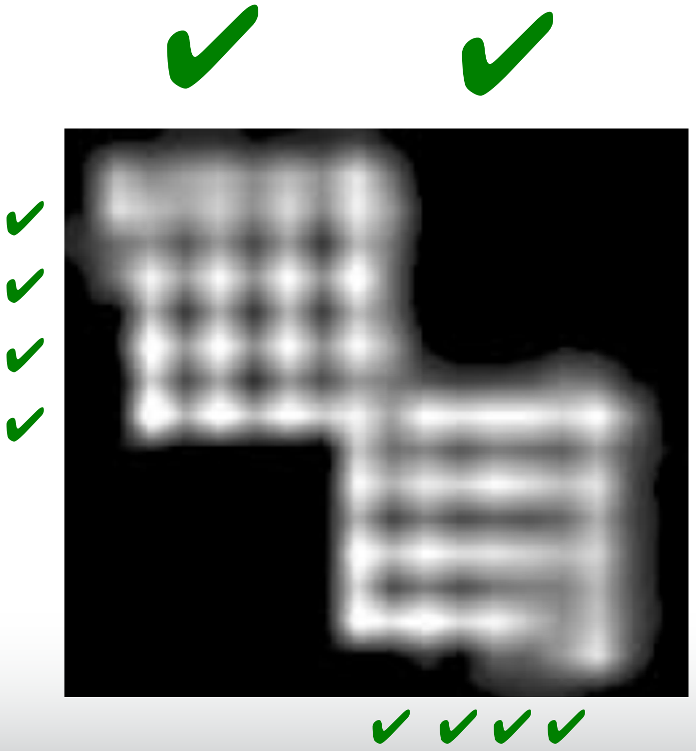
UL (4 holes in a row)

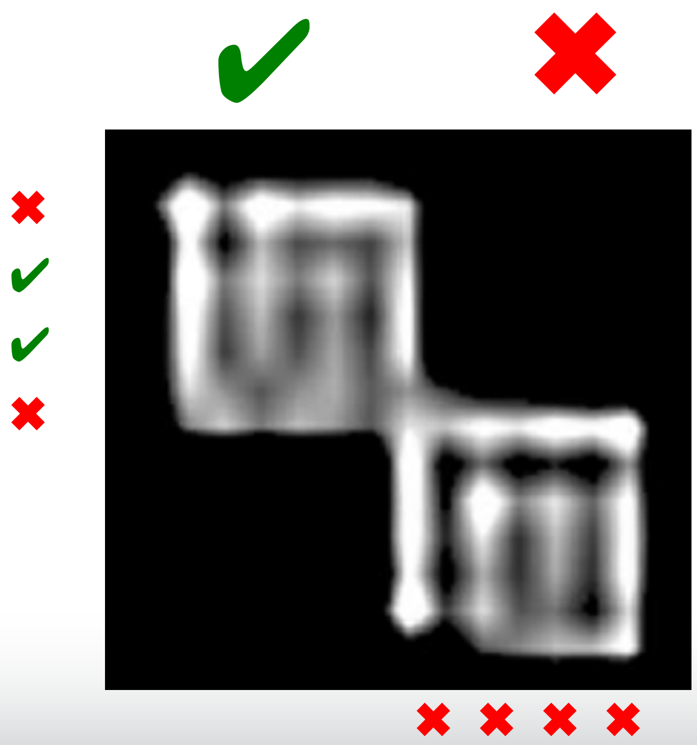


LR (4 holes In a col)



Failure: image filtering is turned on, eddy currents, ghosting, gradient issues.





Low-Contrast Detectability

Slice 8-11. Start with 11, then move backwards.

- Adjust contrast to see all three disks on a spoke.
- Ragged disk=ok; not visible=no spoke.
- First missing spoke clockwise = done with counting on this slice.

Pass: <3T: 9 out of 40; 3T: 37 out of 40

Failure: poor alignment, poor SNR, ghosting, poor uniformity, coil issues, old phantom**

Low-Contrast Detectability Recommendations by Field Strength for Large ACR Phantom for the ACR T1 Series			
Field Strength	Recommended weekly QC slice #	Typical number of spokes visible in recommended QC slice	Total number of spokes on all slices
0.2	11	4	12
0.3	11	5–7	21
0.5	10	6–9	27
0.7	10	6–8	31
1.0	9	7–8	34
1.5	8	6–9	36
2.0	8	9–10	38
3.0	8	10	40

Artifacts

"Stuff that matters".

Geometric distortion, ghosting, zippers, gain errors, blurring, susceptibility (large bubble?), strong truncation (low BW).

Motion: give it a rest before scanning again. Or, pad the phantom better (rattle).

Things that don't matter: expected truncation, DC offset artifacts at edge of FOV

Percent Signal Ghosting (PSG)

Slice 7 (ACR T1)

- One circular signal ROI ~ 200cm^2 (~14cm dia) and four bounding noise ROIs ~ 10cm^2.

$$PSG = \left[\frac{(top + btm) - (left + right)}{2 \times (largeROI)} \right]$$

PSG≤2.5% to pass.

Make sure that the noise ROIs are not outside the imaging region.

Failure: motion, scan instability, gradient issues, cable issues – call service person.

Image Intensity Uniformity (PIU)

Why measure uniformity (ACR perspective)?

"Are the images acceptable for clinical usage/ diagnosis*?"*

→ Look at images and characterize whether they are acceptable (ACR test).

Different question from "***Is my machine working properly?***"

→ Test the machine to see if everything is in working order.

ACR Uniformity vs. Equipment Tests

It is possible for ACR uniformity to pass yet equipment is faulty.

It is possible for ACR uniformity to fail (barely) yet equipment is “fine”.

ACR Uniformity test was specified during the era of volume coils.

“Lack of image intensity uniformity suggests a deficiency in the scanner, often a defective volume coil or problem with the radiofrequency subsystems.”

Uniformity is not sufficient for equipment check… and, may not be sufficient for QC, either.

ACR Uniformity (barely, at times)

Uniformity test with 32-channel coil (3T) -- 32 tests with one element turned off (filter on**)

- Uniformity failures:
- All elements: PIU=89.6%
- One missing element: $\langle PIU \rangle_{N-1}$=89.6%
- $s_{PIU,N-1}$=0.5% (SEM~0.1%)

  $PIU_{N-1,min}$=88.0%; $PIU_{N-1,max}$=90.2%

  Original acceptance testing: PIU ~ 81%.

** without which, we cannot pass ACR.

ACR Uniformity (barely, at times)

- Uniformity test with an 8-channel.

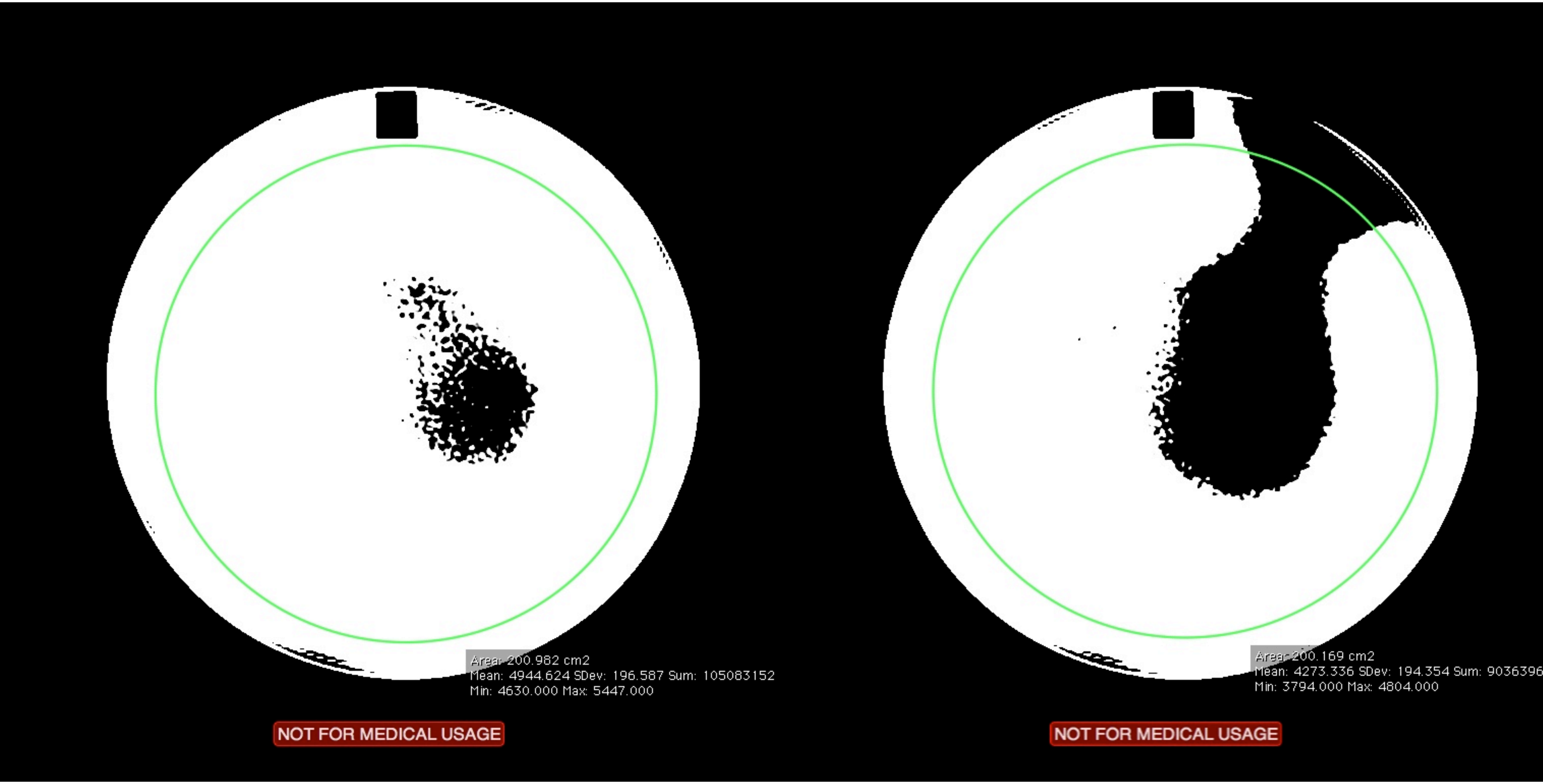
1 test with one element turned off (symmetry in coil)

- All elements: PIU=93.6%
- One missing element:

PIU_{N-1}=91.5%

- Spatial distribution different, even with filter on.

Uniformity and PA Coils



All elements | 7 elements

Image Intensity Uniformity (PIU)

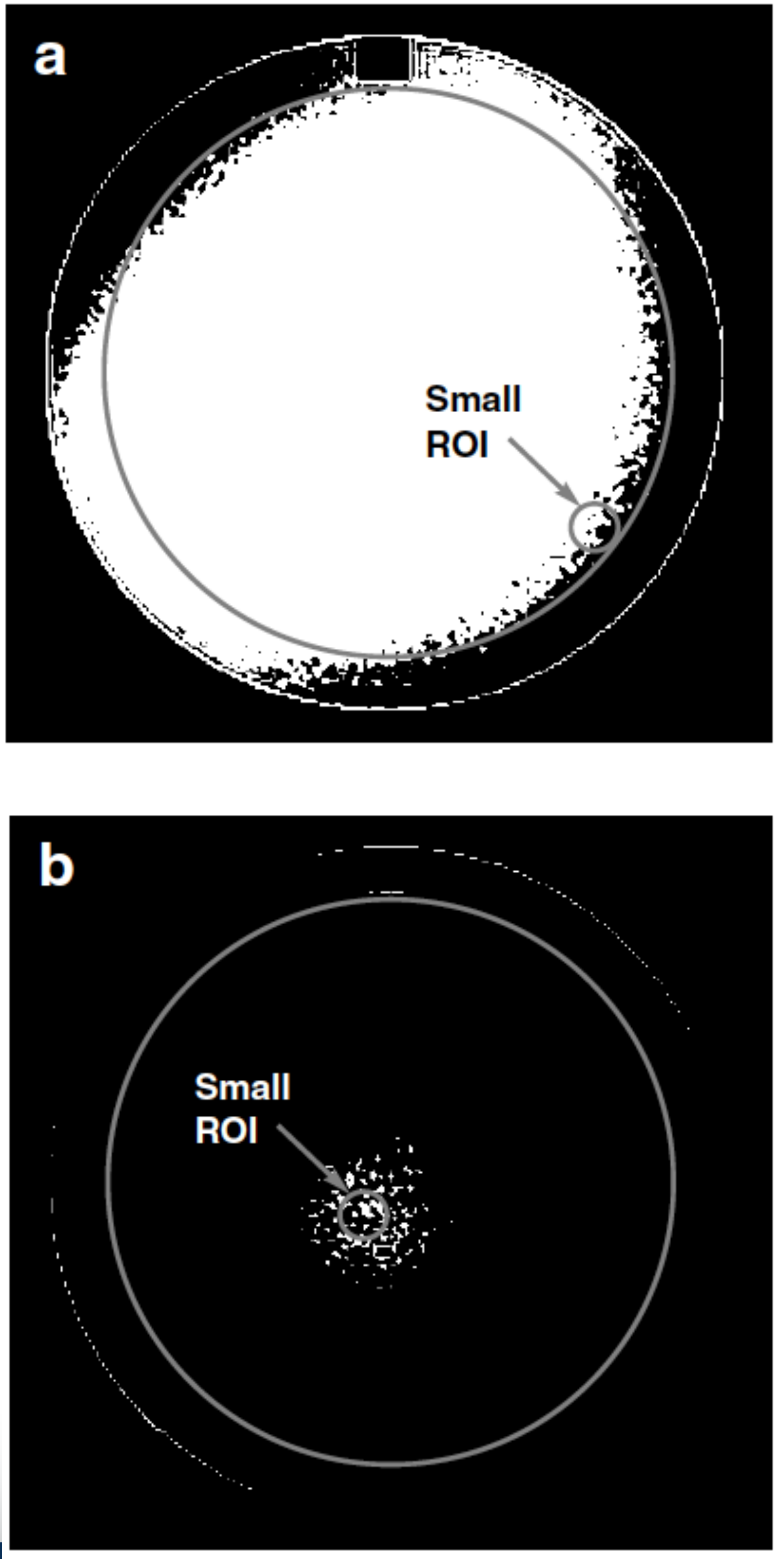
Method (ACR T1 & T2):

- One circular signal ROI ~ 200cm^2 (~14cm dia).
- Set window to 1.
- Lower lever until image is white.
- Raise until a small region of dark pixels is visible → use 1cm^2 ROI to measure "Min".
- Continue until tiny region remains white → use 1cm^2 to measure "Max".

$$PIU = 100 \times \left[1 - \frac{Max - Min}{Max + Min}\right]$$

Pass: PIU(<3T) >87.5; PIU(=3T)>82%

Failure: alignment, nature of coil + uniformity filter.



Monitoring of QC Procedures

Need to look back at weekly QC and sign off on it.

In our facility, sometimes we develop “workarounds” that help with throughput (but not quality). So, problems aren’t mentioned.

Problems:

Infrequent QC

Failures not getting noticed (are action limits posted?)

Useful advice:

Have one/two techs assigned to this.

When issues arise, you need to document this and provide comments to the site. That’s your job.

Monitoring of QC Procedures

Make sure that QC is performed regularly

2013 Date	Table OK?	Console OK?	CF (Hz) f0 ± 1000 hz res. freq. (Hz)	TX Gain/ Attenuation PU 2/4 .92-.96 ds1	PU 4/4 .93-.97 ds2	Phantom Distances (mm) H/F (148)	A/P (190)	R/L (190)	Slice 1 HR Holes UL	LR	Slice # 8 Number of LCD Spokes	Artifacts ?
Action Limits --->						148±2	190±2	190±2	≤ 1.1	≤ 1.1	≥ 7	
8/15	✓	✓	127749646	.9492	.9538	146	190	190	1.0	1.0	10	—
8/20	✓	✓	127749553	.9534	.9570	146	190	190	1.0	1.0	10	—
9/9	✓	✓	127749 343	.8978	.9071	146	190	190	1.0	1.0	10	—
9/9	✓	✓	127749 330	.8964	.9064	146	190	190	1.0	1.0	10	—
9/12	✓	✓	127749512	.8965	.9024	146	190	190	1.0	1.0	10	—
10/17	✓	✓	127748888	.8933	.9012	146	190	190	1.0	1.0	10	—
10/11	✓	✓	127748840	.8848	.8962	146	190	190	1.0	1.0	10	—
12/09	✓	✓	127748603	.8903	.8958	146	190	190	1.0	1.0	10	—
2/0[illegible]	✓	✓	12774[illegible]1658	.8769	.8844	146	190	190	1.0	1.0	10	[illegible]
2/2[illegible]	✓	✓	127747684	.8759	.8803	146	190	190	1.0	1.0	10	—
~~3/11~~	✓	✓										
3/17	✓	✓	127747622	.8832	.8882	146	190	190	1.0	1.0	10	Bubble

Tech brought to our attention that the CF had jumped “significantly”.

Actually, it was an indication that we hadn’t been keeping track of scans.

- Whose fault? Both mine and techs.

New Stuff:
MR Site Safety and Annual ACR Testing

MR Site Safety: Physicist Requirements

ACR criteria for compliance:

- Written polices are present and readily available to facility staff.
- Written policies are reviewed and updated on a regular basis.
- Facility has appropriate MR safety warning signage and methods of controlled access.
- Documentation of regular MR safety training for all MR-designated personnel.

ACR MP Site Safety Checklist

The following topics must be addressed in written site policies:

Designated MR Medical Director
Site Access Restrictions (MR Zones)
Documented MR Safety Education/Training for all personnel***
Patient and non MR Personnel Screening
Pediatric Patient 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
Designation of MR Safe/MR Conditional status
Procedures for Reporting MR Safety Incidents or Adverse Incidents
Patient Communication
Infection Control Criteria

Magnetic Field Homogeneity Testing

Why Test Homogeneity?

- Precise spatial encoding requires well-known field configuration (usually, homogeneity).
- Problems with poor homogeneity:

Poor signal uniformity

Image distortion

Increased wrap

Sequence related problems (fat sat, EPI, spectroscopy).

Solution: Use GRE-type of sequence to probe T2* over field of view.

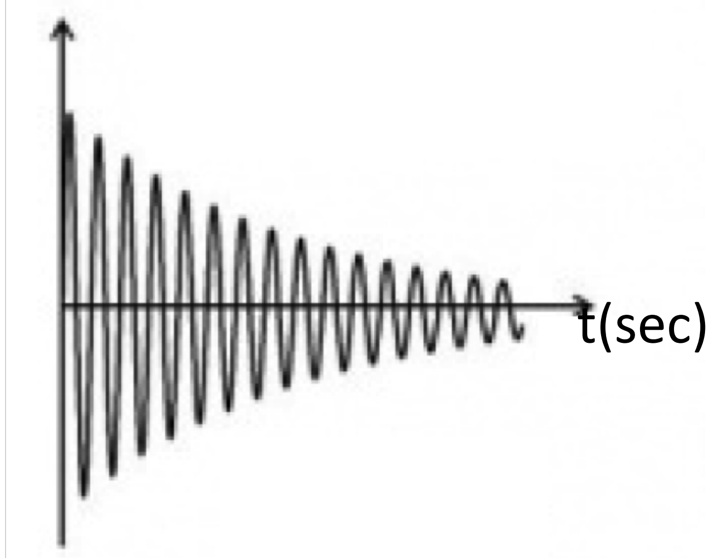
Homogeneity Methods

- Spectral Peak Option
- Phase-Difference Map Method
- Phase-Map Method
- Bandwidth-Difference Option
- Also, one may use the service engineer's recent shim report (< 6 mos old for validity).
- Vendor details at http://wikifull.aapm.org/index.php/WGMRQA

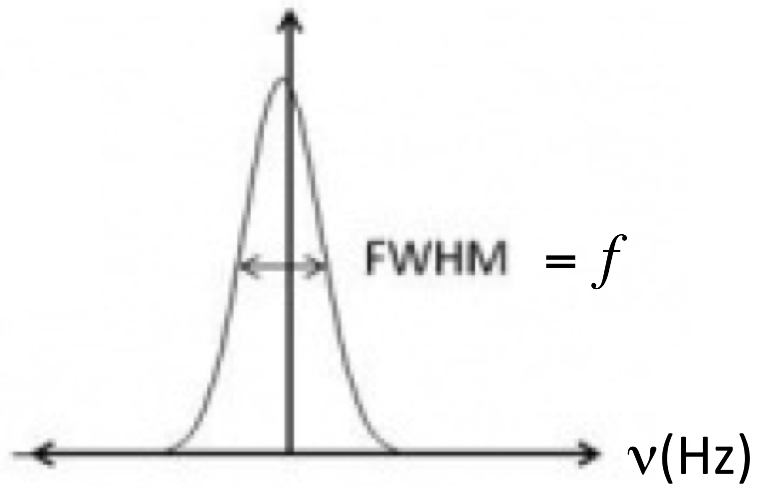
- Survey: How many people are currently using any of these?

Method #1: Spectral Peak

Excite water within a phantom.



$$S(t) = M_0 \sin(2\pi\nu) e^{-t/T2^*}$$



$$F(\nu) = \frac{A}{\pi}\left(\frac{f/2}{(\nu - \nu_0)^2 + (f/2)^2}\right)$$

Exponential decay → lorentzian after transform

Spatial variation of inhomogeneities within phantom → variation from lorentzian

Pro: Quick/easy to measure – NO IMAGE!

Con: details are “averaged” within shape.

Method #1: Spectral Peak

Need to use spherical phantom.

"The phantom should have a spherical volume diameter <u>similar to that cited by the manufacturer's homogeneity</u>"

- Big DSV – total system homogeneity.
- Small DSV – best homogeneity available.
- Peak shape – shim issues (qualitative).

Put phantom at isocenter of scanner.

Placement is very important. x,y(!!!!), and z

Measure the FWHM of a spectrum:

$FWHM(ppm) = FWHM(Hz)/42.576xB_0\,(T)$

Method #1: Spectral Peak

At our institution, we measure a variety of sizes for one particular scanner.

- Captures history.
- Captures some shimming detail.
- Relates our measurements to instrument specs.

Site Augusta University Medical Center　　Date 06/06/17
MRAP Number 01032-06　　Serial Number 42185
Equipment
MRI System Manufacturer Philips　　Model Ingenia 3T
Film Processor manufacturer N/A　　Model N/A
PACS Manufacturer Philips　　Model IntelliSpace PACS
ACR MRAP Phantom Number used J2234
1. Magnetic Field Homogeneity
Method Used　　Spectral Peak X　　Phase Difference ____
Other: FWHM was used to assess homogeneity

Diameter of Spherical Volume	Phantom	FWHM (ppm)	Results	Date
10	Philips spectroscopy	16 (0.125)	Baseline	7/7/12
10	GE 3T sphere	66 (0.516)	Baseline	7/7/12
15.8	GE 3T sphere	70 (0.547)	Baseline	7/7/12
31.7	GE 3T sphere	80 (0.625)	Baseline	7/7/12
10	Philips spectroscopy	23.5 (0.184)	Satisfactory	8/5/13
10	GE 3T sphere (#1)	84 (0.658)	Satisfactory	8/5/13
15.8	GE 3T sphere	87.5 (0.685)	Satisfactory	8/5/13
31.7	GE 3T sphere	91 (0.712)	Satisfactory	8/5/13
10	Philips spectroscopy	32 (0.25)	Satisfactory	4/8/14
10	Philips spectroscopy	40 (0.31)	Satisfactory	4/8/14
10	GE 3T sphere (#1)	63 (0.49)	Satisfactory	4/8/14
15.8	GE 3T sphere	95 (0.74)	Satisfactory	4/8/14
31.7	GE 3T sphere	82 (0.64)	Satisfactory	4/8/14
10	Philips spectroscopy	32 (0.25)	Satisfactory	5/19/15
10	GE 3T sphere (#1)	74 (0.58)	Satisfactory	5/19/15
15.8	GE 3T sphere	71 (0.56)	Satisfactory	5/19/15
31.7	GE 3T sphere	84 (0.66)	Satisfactory	5/19/15
10	Philips spectroscopy	8 (.062)	Satisfactory	6/14/16
10	GE 3T sphere (LOT# 52001BTMF)	35 (0.274)	Satisfactory	6/14/16
15.8	GE 3T sphere	37 (0.29)	Satisfactory	6/14/16
31.7	GE 3T sphere	37 (0.29)	Satisfactory	6/14/16
10	Philips spectroscopy	19 (0.15)	Satisfactory	6/6/17
10	GE 3T sphere (LOT# 52001BTMF)	53.5 (0.41)	Satisfactory	6/6/17
15.8	GE 3T sphere	47.5 (0.37)	Satisfactory	6/6/17
31.7	GE 3T sphere	66 (0.52)	Satisfactory	6/6/17

The Q-Body coil was selected (not the dS Posterior coil).
Philips document entitled "Finding FWHM of MR Scan Spectra" was used to measure FWHM.
ACR T1 protocol for prescan was used for prescan.

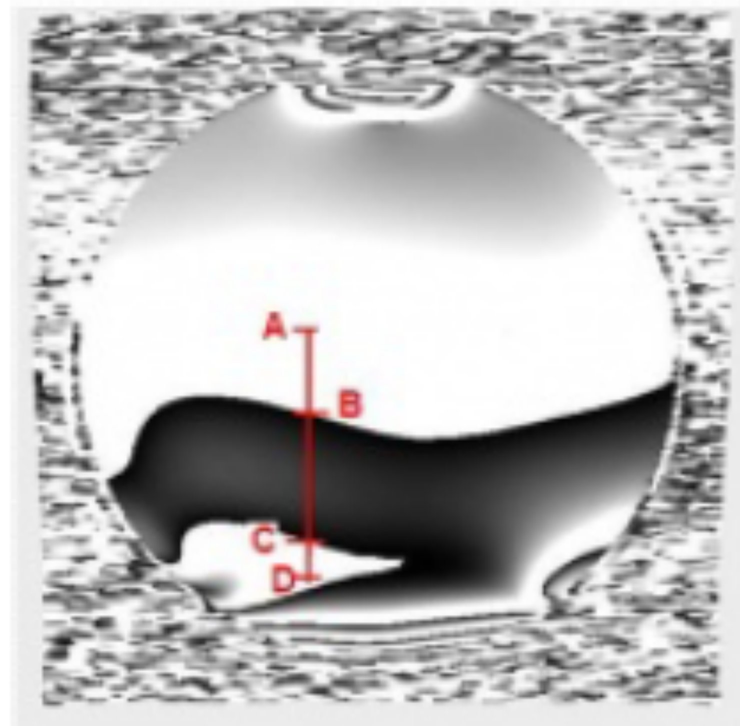
Method #2: Phase-Difference Mapping

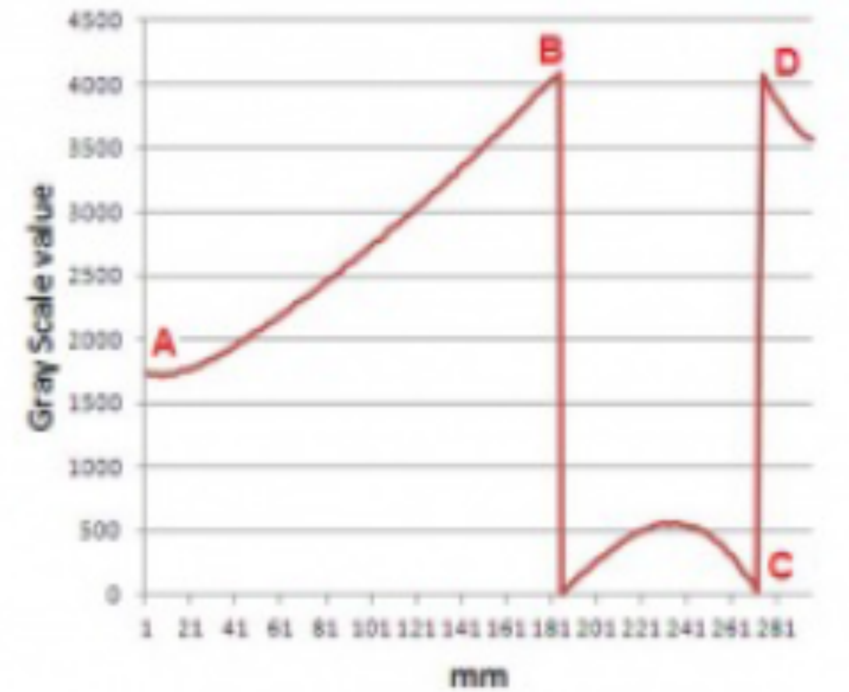
If field were uniform, phase map would show monochromatic value across space.

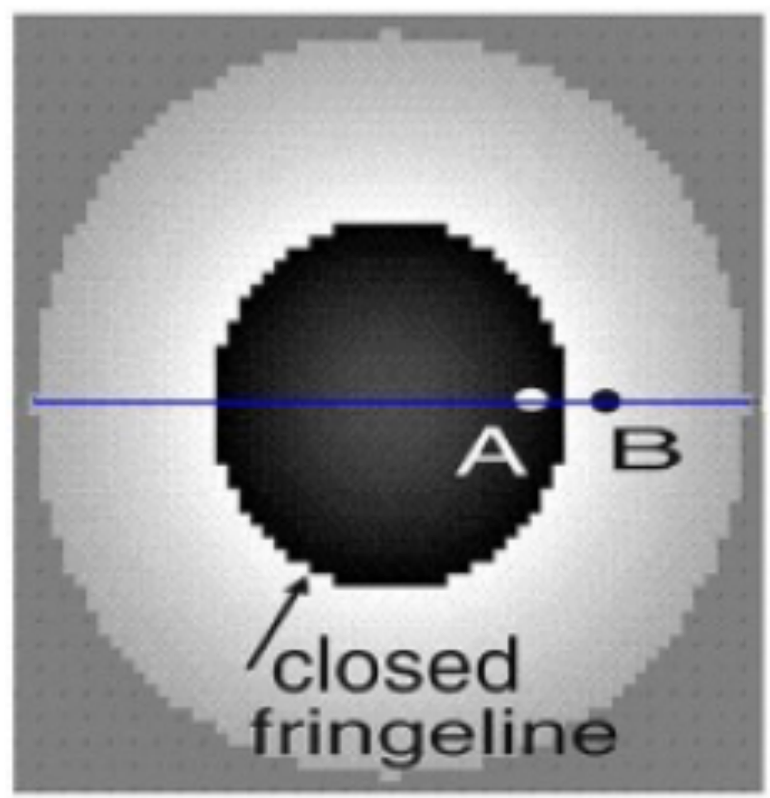
Non-uniform phase → field differences.

Pro: see volume detail.

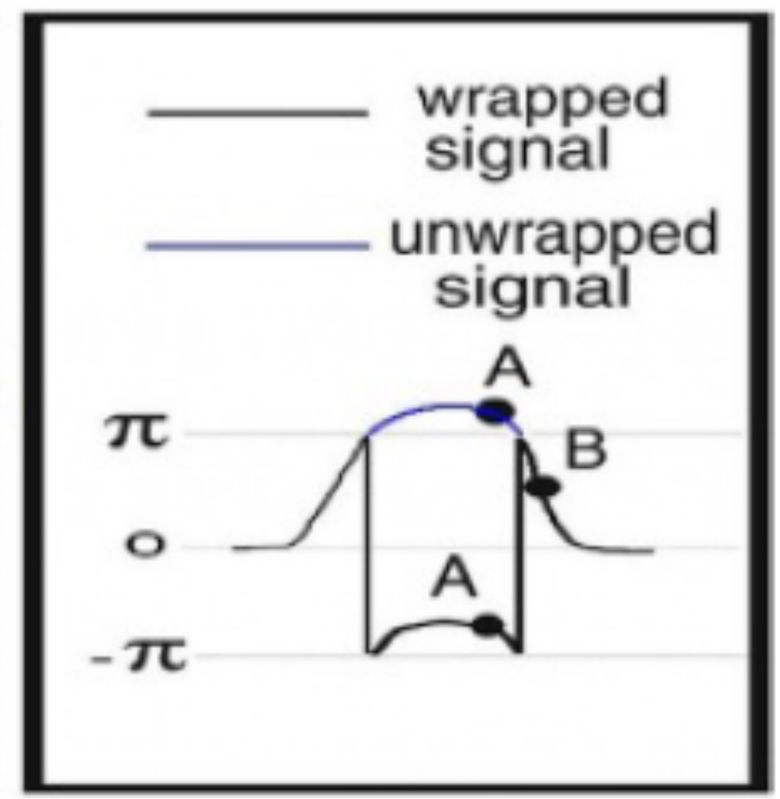
Con: phase images?







(a)



(b)

Method #2: Phase-Difference Mapping

How to use this for a test?

Acquire two phase maps at similar TE.

Change in homogeneity from difference in phase:

$$\Delta B_0(x,y,z) = \frac{\delta\phi(x,y,z)}{\gamma}\left[\frac{1}{TE_1 - TE_2}\right] \rightarrow \Delta B_0(ppm) = \left[\frac{\delta\phi}{\Delta TE(\sec)\times 42.58 \times B_0(T)}\right]$$

To generalize to full ROI and compare to scanner specs, use one of the two:

$$\delta\phi(peak-to-peak) = \frac{\left[ROI_{\max} - ROI_{\min}\right]}{ADC_{dynamicRange}}$$

$$\delta\phi(rms) = \frac{\sqrt{(ROI_{stdev})^2 (ROI_{mean})^2}}{ADC_{dynamicRange}}$$

In ROI, make measurements:

ROImax = maximum pixel value in ROI, etc…

Method #2: Phase-Difference Mapping

Method:

Place uniform phantom in center of magnet.

The size of the phantom should be appropriate for the diameter to be assessed, and, in general, the larger the better. A spherical phantom is preferable…

Need to use a gradient echo (need T2*). 2D or 3D.

Suggested protocol:

Dual-echo GRE (if available) – avoids rescaling

$TR/TE_1/TE_2$=(300-500/10-15/TE_1+2-10)msec,

FOV=25-40cm, flip=25-40, matrix: 128x128 or 256x256.

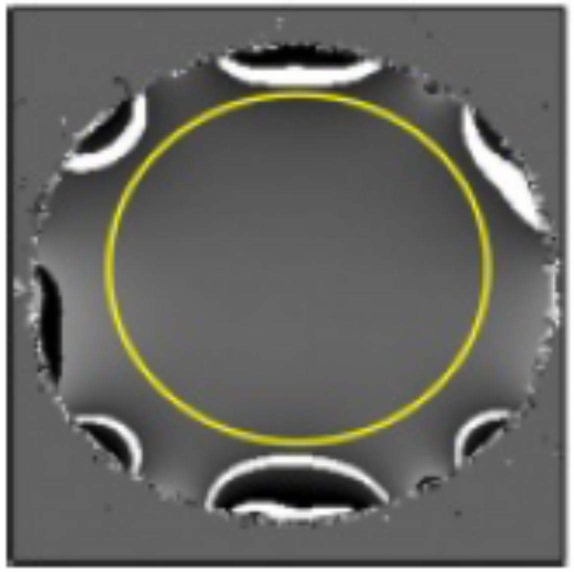
Method #2: Phase-Difference Mapping

Method:

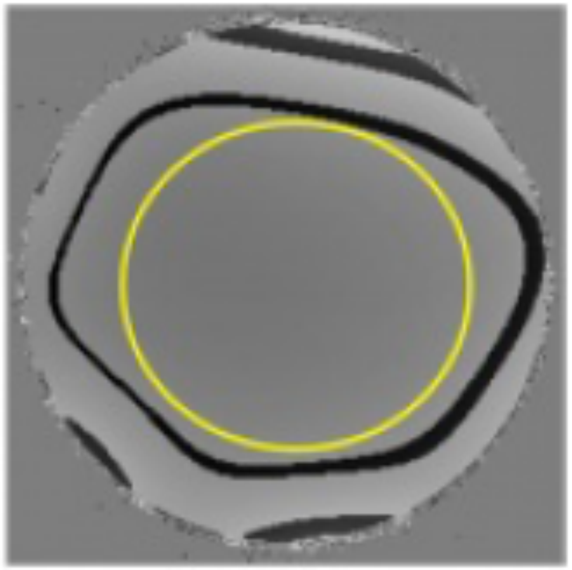
Subtract the two images (scanner, or ImageJ). Need to pay attention to regions of phase wrapping.

Choose region that avoids phase wrapping issues.

If wrap is near the middle, use different TEs.



Phase map



Phase difference

Finding $ADC_{dynamicRange}$: depends on the vendor.

Represents the range of pixel intensity values per 2π.

Method #3: Phase (Field) Mapping

Vendor-specific methods for using phase maps to create a three-dimensional field map.

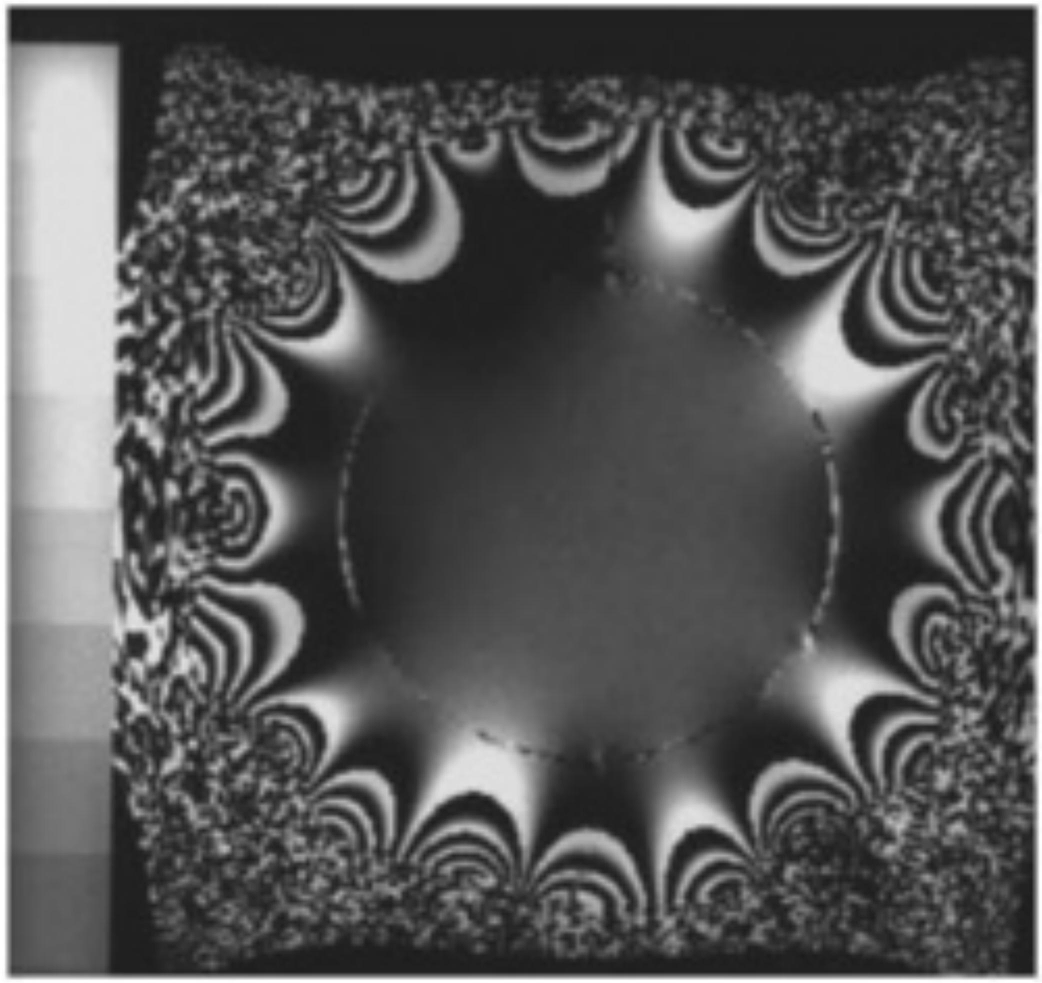
Either uses 2D stack or 3D acquisition.

GE: LVshim

Siemens: Phantom Shim.

Pro: most thorough way to assess field homogeneity.

Con: service measurement (not available to all).



For details, see

http://wikifull.aapm.org/index.php/WGMRQA

Notes on Phase Mapping Methods

Pro that is a con: phase maps give detailed info over full volume.

→ One slice in through isocenter in three orientations is not enough.

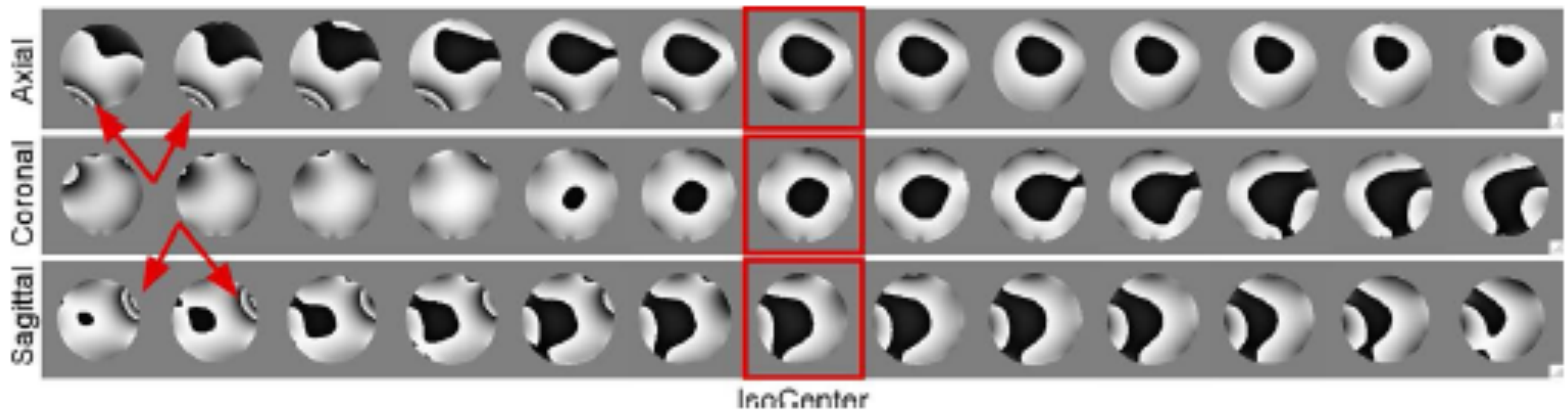


Figure 8. A series of multiplanar reformatted phase images from a 3-D GRE scan. The slices through isocenter (red boxes) appear completely normal. The images on the far left, indicated by the red arrows, show a well-defined region of field inhomogeneity that was caused by a bobby pin under the magnet bore cover.

Method #4: Bandwidth

Poor homogeneity can lead to image distortion.

FOV_{FE} is connected to spatial encoding via F-E bandwidth (i.e., Hz per pixel?).

Inhomogeneity → spatial scale is off → F-E is not what we observe.

By acquiring images at two different receiver bandwidths, we can determine the amount of distortion in the F-E direction.

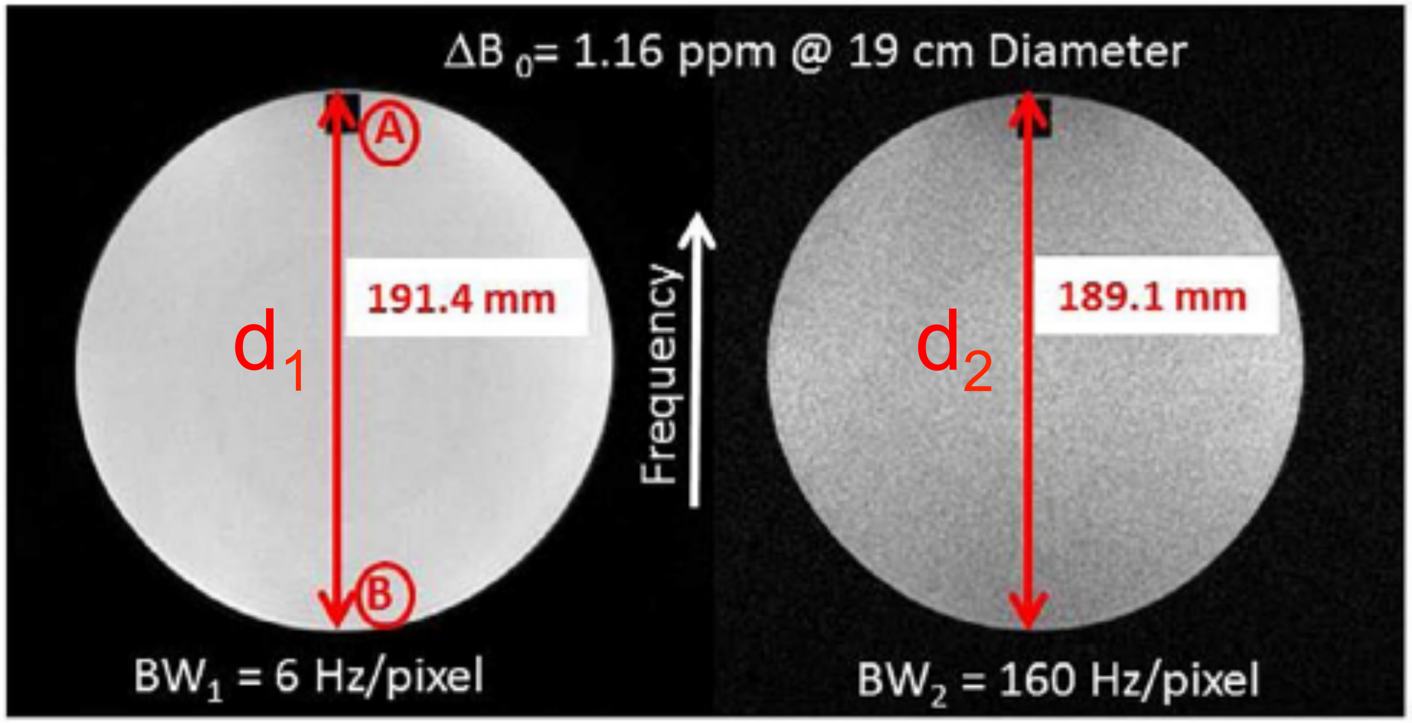
Chen, et al., Med. Phys. 2006

$$\Delta B_0(ppm) = \left[\frac{(BW_1 \times BW_2) \times (d_1(mm) - d_2(mm))}{42.58 \times B_0(T) \times FOV_{FE}(mm) \times (BW_2 - BW_1)} \right]$$

d_1, d_2 = phantom size measured from image.

Method #4: Bandwidth

$$\Delta B_0(ppm) = \left[\frac{(BW_1 \times BW_2) \times (d_1(mm) - d_2(mm))}{42.58 \times B_0(T) \times FOV_{FE}(mm) \times (BW_2 - BW_1)} \right]$$



Pro: can perform this test with no vendor scanner tools available.

Con: need at least three images (F-E along axial, sagittal, coronal). Not as thorough as phase maps.

Can use SE or GRE sequences.

Method #4: Bandwidth

Method:

Put spherical phantom at isocenter of scanner.

Placement is very important. x,y(!!!!), and z.

Use phantom with appropriate DSV.

Gradient echo series: square matrix. 1 slice.

Acquire two images, each at different BW.

Do this for F-E along x, y, z.

Measure across the full DSV of phantom.

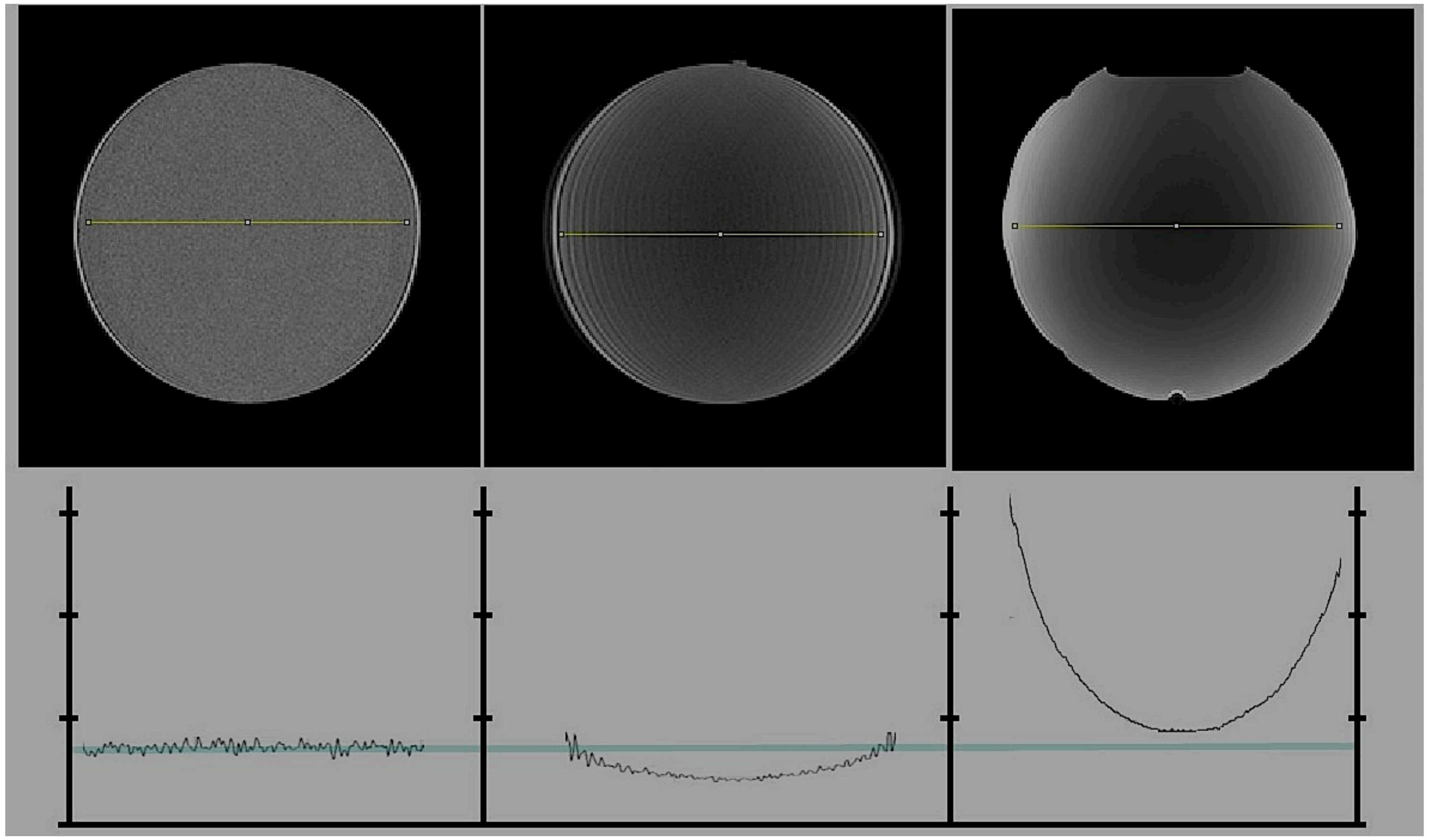
MRI SNR Coil Tests

Coil Testing, in General

Make sure to inspect cables for damage.

Volume vs. Surface vs. Phased Array

-- PIU and SNR need special consideration.



Uniformity filters (e.g., SCIC) are needed for PA coils to pass ACR PIU test, but they hide element failures.

SNR Coil Testing

Question: how do you test your coils?

Option #1: ACR recommendations (set action limits)

- Volume: Single-image SNR method
- Volume: Dual-image SNR method
- Surface Coil testing: max, mean SNR
- Phased-Array Coil testing: single-image SNR
- Testing all elements

Option #2: service-type testing (limits set for you)

Most important: reproducibility (procedures, ROI size/ placement, phantom, documentation)

SNR Coil Testing

"For the purpose of this test, flexible coils are considered to be surface coils. For multi-channel coils, it is recommened to test individual channel elements separately."

Uniformity doesn't cut it anymore for equipment health survey, so try the two-pronged approach for SNR as well (if not using service tool):

- Global SNR test (quantitative value)
- Individual element inspection (qualitative→ quantitative if necessary): signal and noise images.

We need a better way to do this quickly!

Don't forget the last part if using service tools.

SNR Coil Testing & Phantoms

Usually, coils come with special phantoms.

If not, use what matches coverage the best (ACR phantom is usually not very good for other anatomy).

E.g., cylinder/sphere → head/shoulder coil

bottle → knee coil

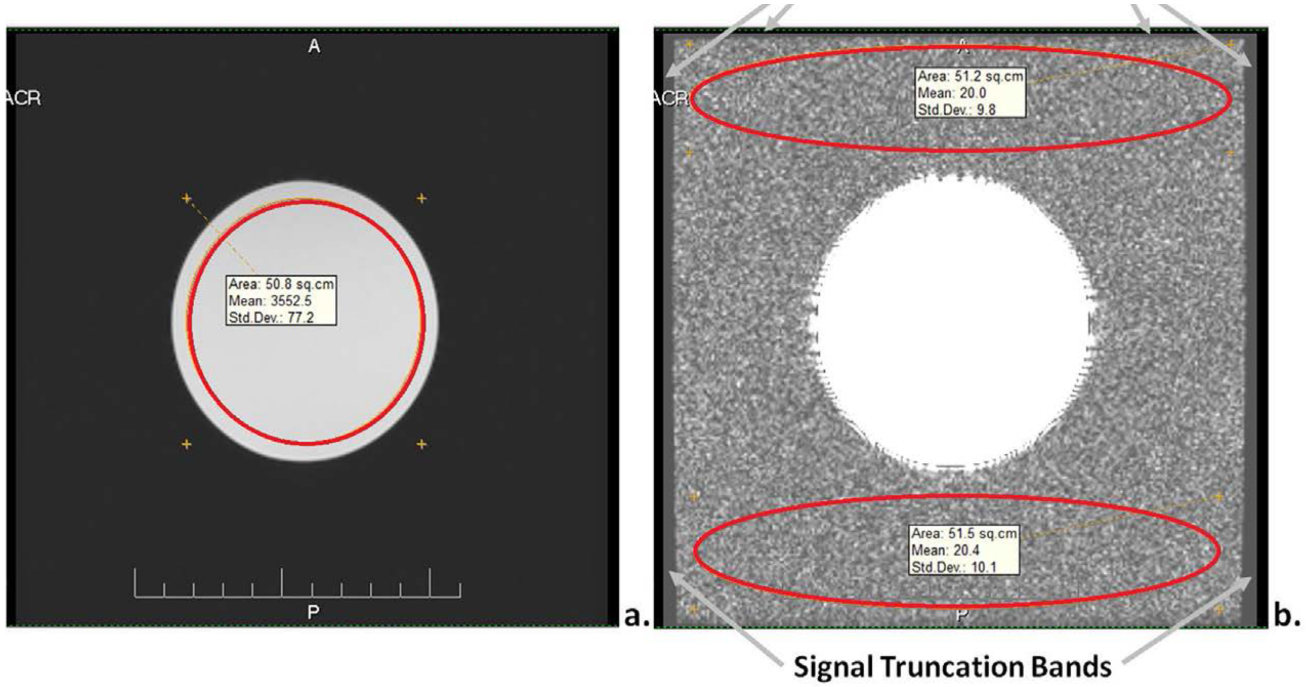
multiple spheres → breast coils

multiple bottles or rectangular tank → anterior coils

Testing Protocol: ACR T1 is a good start.

SNR Coil Testing (ACR methods)

Single-image Method: $SNR_{single} = signal / \sigma_{tot}$



Only one image needed – speed and simplicity.

Signal: mean in central ROI

Noise: std dev in outer ROIs. $\sigma_{tot} = \sqrt{\sum_i \sigma_i^2}$

ROI tips: maximize signal ROI while keeping it out of non-uniformity regions (PA coils).

Don’t choose std dev ROI in truncated region.

SNR Coil Testing

Single-image Method (NEMA variant):

$$SNR_{NEMA} = 0.655 \times signal / \sigma_{air}$$

This is more quantitatively correct, as the noise distribution for a single-channel coil is Rician:

~ Gaussian in areas of high SNR

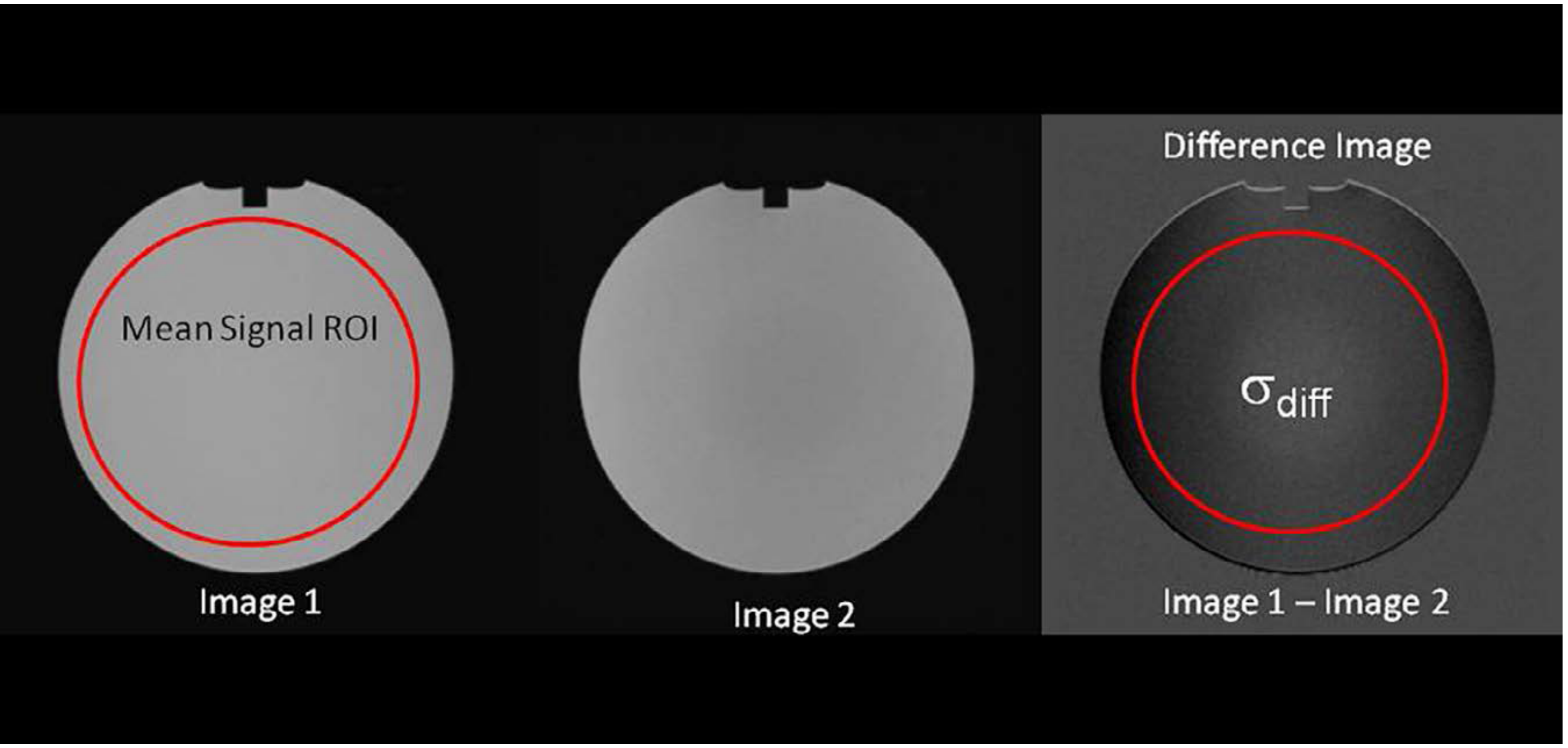
~ Rayleigh in areas of low SNR

Whatever method you choose, <u>use the same one consistently!</u>

For QC, what matters is the current value compared to action limits, not the absolute quantitative amount.

SNR Coil Testing (ACR methods)

Double-image Method: $SNR_{double} = \sqrt{2}M / \sigma_S$



Scan two duplicate images.

M = sum of both

S = difference of both

Allows for direct assessment of noise in the same ROI. (why is this good? Rician…and, for parallel imaging QC in future, key).

SNR Coil Testing (ACR methods)

Surface Coils (Max/Mean):

Select image in center plane of phantom.

Adjust window to see signal variations.

Small measurement ROI (>1cm^2)

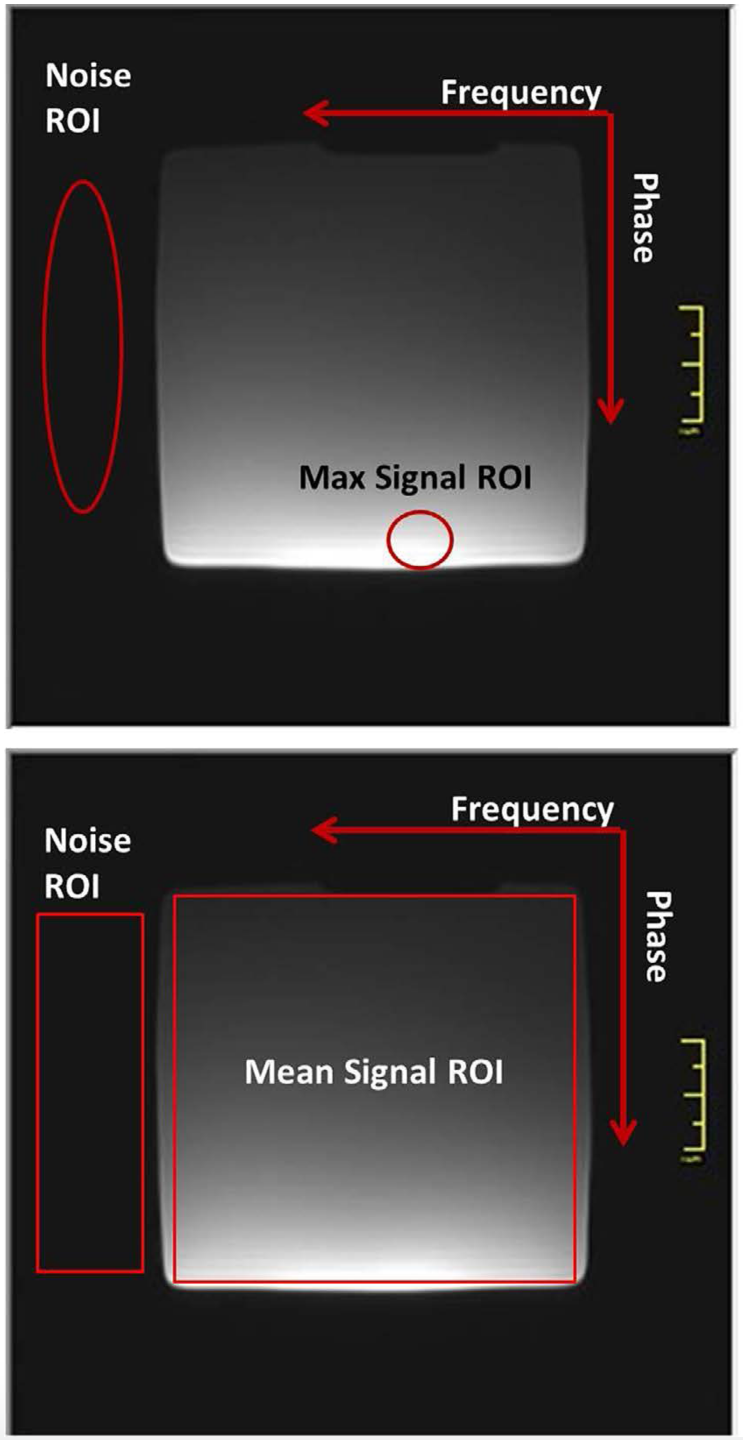
→ measure Max signal

Large measurement ROI (covers much of Phantom)

→ Measure mean signal

Noise ROI outside of phantom

$$SNR = max, mean / \sigma_{noise}$$



Testing Efficiently

Key rule of thumb:

Only assess coils that you use!

Take a survey of the techs to answer this question.

Barely-used coils: put them in the equipment room. If MP is onsite, then survey them before a use.

Example: we have two sets of surface coils, and we have two anterior torso coils. Mark with tape as “spare”, put them in storage in case of emergency.

Don’t forget the body transmit, though.

Testing Efficiently

What about new coils and putting a coil into service?

Test the coil accordingly as you would at an annual before using it (to ensure quality).

At annual renewal time, repeat the testing, and report the new coil to ACR.

For taking coils out of service, just note what coils you're using at the time, and drop testing for irrelevant coils.

Testing Efficiently

Come up with a site-specific testing sheet for your coils.

8. RF Coil Performance Evaluation **Date** 06/06/17

RF Coil

RF Coil description: SENSE HEAD 32

Test: IQT (Philips service software)

Test performed by: Drs. Allison and Yanasak

Coil Element	SNR	Specification	Pass/Fail
1	120.97	91	Pass
10	106.49	83	Pass
11	124.46	90	Pass
12	103.07	84	Pass
13	98.14	86	Pass
14	103.28	78	Pass
15	88.83	72	Pass
16	116.44	92	Pass
17	100.81	81	Pass
18	97.04	79	Pass
19	103.36	84	Pass
2	110.22	87	Pass
20	99.05	80	Pass
21	113.06	98	Pass
22	142.23	105	Pass
24	119.07	81	Pass
25	105.66	91	Pass
26	102.1	83	Pass
27	100.15	82	Pass
28	97.63	83	Pass
29	98.18	83	Pass
3	98.9	83	Pass
30	116.83	89	Pass
31	111.49	92	Pass
32	103.15	85	Pass
4	123.64	100	Pass
5	92.94	80	Pass
6	115.61	90	Pass
7	93.16	80	Pass
8	90.17	83	Pass
9	123.33	93	Pass
SC	114.96	102	Pass
TC	105.1	97	Pass

Uniformity satisfactory

Ghosting satisfactory

Artifacts satisfactory

8. RF Coil Performance Evaluation **Date** 06/06/17

RF Coil

RF Coil description: NVC HEAD

Test: IQT (Philips service software)

Test performed by: Drs. Allison and Yanasak

Coil Element	SNR	Specification	Pass/Fail
10	140.22	107	Pass
11	112.43	92	Pass
12	85.52	64	Pass
13	123.53	97	Pass
14	77.79	58	Pass
15	105.13	77	Pass
9	108.65	83	Pass
1	146.61	103	Pass
2	145.84	103	Pass
3	117.64	81	Pass
4	103.4	77	Pass
5	76.79	52	Pass
6	91.91	67	Pass
7	88.04	60	Pass
8	92.75	67	Pass

Uniformity satisfactory

Ghosting satisfactory

Artifacts satisfactory

Testing Efficiently

If using system tools for tests, if the coil passes or fails, make sure to check the quality of signal and noise images.

“Upper limits” on SNR? Probably a good idea…

E.g., a torso array coil with a spec ~ 180 SNR passed with a 100,000 SNR! Further inspection showed that signal was rather low, and the noise was virtually zero.

Summary

- New ACR annual requirements are somewhat similar to pre-2015 requirements.
- A few new tests and recommendations available (table position, homogeneity, SNR).
- Weekly stuff needs to be repeated by MP annually.
- Annual programmatic safety assessment is now going to be an important part of our job for ACR.

Questions?