Physicist's Role in ACR MRAP Accreditation

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Carl R. Keener, Ph.D., DABMP, DABR
keener@MARPinc.com

MARP
Medical & Radiation Physics, Inc.

GRADUATE SCHOOL OF BIOMEDICAL SCIENCES
UT HEALTH SCIENCE CENTER™
SAN ANTONIO

disclosure

- ACR MRAP Physics subcommittee
- ACR MRAP phantom reviewer
- consulting diagnostic physicist
  - GE, Siemens, Philips, Toshiba, Marconi, Hitachi, Fonar
  - 0.2T – 3T
  - MRI surveys
    - 2006 – 17 surveys
    - 2007 – 33 surveys
    - 2008 – 48 surveys
    - 2009 – 43 surveys

accreditation

- United Healthcare will require accreditation for reimbursement by 4th quarter of 2009
  - MRAP (ACR)
  - ICAMRL (IAC)
  - outpatient imaging centers
  - accreditation started by Dec. 31, 2009
- Medicare Improvements for Patients and Providers Act (MIPPA)
  - providers of advanced imaging services to be accredited by January 1, 2012
    - Part B
  - ACR
  - IAC
  - TJC

ACR MRAP vs IAC ICAMRL

- **MARP MRI surveys**
  - **43 accredited MRI clients**
    - **42 ACR (2 in process)**
    - **1 IAC**
    - **2 expired**
  - **54 MRI scanners**
- **MARP CT surveys**
  - **43 accredited CT clients**
    - **41 ACR (2 in process)**
    - **2 IAC**
  - **146 CT scanners**

ACR accreditation process & phantom

- ACR accreditation process
  - online application
    - information
      - contact
      - site
      - personnel
      - MRI unit
    - selection of modalities & exams
    - payment
  - submission
    - clinical Images
    - phantom Images
  - continuing requirements of accreditation
- phantom & phantom tests

online application

- online application
  - Section 1:
    - contact and general site information
  - Section 2:
    - MRI unit information
    - selection of modalities & exams
  - Section 3:
    - personnel information
      - physicians
      - medical physicists / MR scientist
      - technologist
    - payment
  - 45-day submission window starts at payment

online application

- information
  - magnet
  - practice
- credentials
  - physicians
  - technologists
  - physicists
- modules
  - head
  - spine
  - MSK
  - body
  - MRA
  - cardiac
- fees
  - Accreditation / Reinstate
    - $2400 for 1 - 4 modules
    - $2600 for 5 modules
    - $2800 for 6 modules
  - subsequent magnets / same site
    - $2300 for 1 - 4 modules
    - $2500 for 5 modules
    - $2700 for 6 modules
  - repeat
    - $800 for phantom or clinical
    - $1600 for both
- all magnets at site must be accredited
- 45 day submission period begins

qualifications & responsibilities

- **MRI supervising physician**
  - responsible for MRI protocols
  - approves all aspects of the testing materials submission before sending them to the ACR
- **lead MRI technologist**
  - main contact person with ACR
  - should be the primary person who completes accreditation forms and documents
- **qualified medical physicist / MR scientist**
  - should be responsible for supervising your facility's weekly QC and the annual system performance evaluation
    - MRI FAQs v1.1.doc
  - closely involved with the phantom portion of your testing materials submission
  - assist the supervising physician and lead technologist with your routine clinical protocols

physicist – initial qualifications (January 1, 2010)

- **Board Certified**
  - American Board of Radiology or
    - Diagnostic Radiological Physics or Radiological Physics
  - American Board of Medical Physics or
    - Diagnostic Imaging Physics or Magnetic Resonance Imaging Physics
  - Canadian College of Physicists in Medicine or
    - Diagnostic Radiology Physics or Magnetic Resonance Imaging Physics

OR

- **Not Board Certified in Required Subspecialty**
  - Graduate degree in medical physics, radiologic physics, physics, or other relevant physical science or engineering discipline from an accredited institution, *and*
  - Formal coursework in the biological sciences with at least
    - 1 course in biology or radiation biology, and
    - 1 course in anatomy, physiology, or similar topics related to the practice of medical physics
  - 3 years of documented experience in a clinical MRI environment

OR

- **Grandfathered**
  - Conducted surveys of at least 3 MRI units between January 1, 2007 and January 1, 2010

MR scientist

- graduate degree in a physical science involving nuclear MR or MRI
- 3 years documented experience in a clinical MRI environment

physicist – continuing qualifications

- **experience**
  - **2 MRI surveys in 24 months**
- **education**
  - **15 CMEs in MRI in 36 months**
    - **½ category 1**

ACR accreditation - initial questions????

- when is the due date?
  - has the initial fee been sent?
- is there an ACR phantom?
  - has it been ordered
  - are there manufacturer phantoms?
- is there a laser printer?
  - is there a densitometer?
- can CD-ROMs be burned?
  - from scanner?
  - from PACS?
- how much will you do?
  - evaluation
  - phantom
  - QC
  - paperwork /webwork for submission
  - clinical images

submission

- ACR clinical image and phantom review
  - sent by ACR after receiving application
    - arrives ~ 30 days after application
  - includes MRAP number and due date
    - due 45 days after application
  - includes instructions, parameter data forms, and labels
    - everything (but labels) is available on-line
      - www.acr.org
  - reaccreditation application similar
  - web-based submissions

clinical images

- required from every magnet at practice location
- 4 sets of images
  - original 14 x 17 films
    - (hard copy submissions only)
    - or refilmed from original tapes or discs
- electronic submission
  - CD-ROM <u>with</u> embedded viewer
  - must include functions of:
    - window/level
    - magnification
    - region of interest
      - area
      - pixel mean
      - pixel standard deviation
    - distance measurement
    - access to DICOM header

- must be obtained within 30 days (before or after) of the acquisition of phantom images

clinical images - evaluation

- radiologist reviews for:
  - pulse sequence and image contrast
  - filming technique (hard copy submissions only)
  - anatomic coverage & imaging planes
  - spatial resolution
  - artifacts
  - exam ID
- should be “best work”
- normal or near normal exams
  - as little pathology as possible
- complete examinations
- volunteers not allowed

clinical images

- **current** (~ Nov 2008)
  - site chooses modalities & exams
    - head
    - spine
    - MSK
    - body
    - MRA
    - cardiac
  - one exam from each modality selected
    - at least one must be a specialty exam
- **former**
  - all sites submitted same 4 series
    - brain
    - cervical spine
    - lumbar spine
    - knee
  - current accreditations have be converted to:
    - head
    - MSK
    - spine

75 accredited facilities found for search.

Advanced Imaging San Marcos

1330 Wonder World Drive
Suite 202
San Marcos, TX 78666
Phone: 512-353-5535

- Head,
- MSK,
- Spine

Expires: 08/21/2011

clinical images

- **head**
  - Brain for transient ischemic attack (TIA)
  - Internal auditory canal (IAC/temporal bone) for hearing loss
  - Brain for suspected demyelinating disease*
  - Pituitary with dynamic contrast enhancement*
  - Orbits for vision loss*
- **spine**
  - Lumbar Spine
  - Thoracic Spine
  - Cervical Spine*
  - Cervical Spine with contrast for intramedullary disease*
- **MSK**
  - Knee such as for internal derangement
  - Shoulder such as for internal derangement
  - Wrist such as for internal derangement*
  - Elbow such as for internal derangement*
  - Forefoot for Morton's neuroma*
- **body**
  - Male pelvis such as for prostate cancer
  - Renal
  - Hepatobiliary to Include MRCP*
  - Female pelvis such as for uterine or adnexal disease*

* specialty exam

clinical images

- **MRA**
  - Brain
  - Carotid
  - Thoracic aorta
  - Distal peripheral runoff
  - High resolution arch and carotid*
  - Abdomen for renal artery stenosis *
- **cardiac**
  - Black blood
  - Basic
  - Delayed enhanced cine 1
  - Delayed enhanced cine 2
  - Delayed enhanced cine + black blood*

* specialty exam

clinical images

- **sites choose modalities**
  - 1-6 modalities selected
- **sites choose exams**
  - 4-6 exams
  - one specialty exam for each module
  - should choose exams they do & do well

- **MR Accreditation Clinical Image Quality Guide**
  - image quality for each exam
- maximum examination time
- required sequences
- pulse sequence & image contrast
- anatomical coverage & imaging planes
- spatial resolution

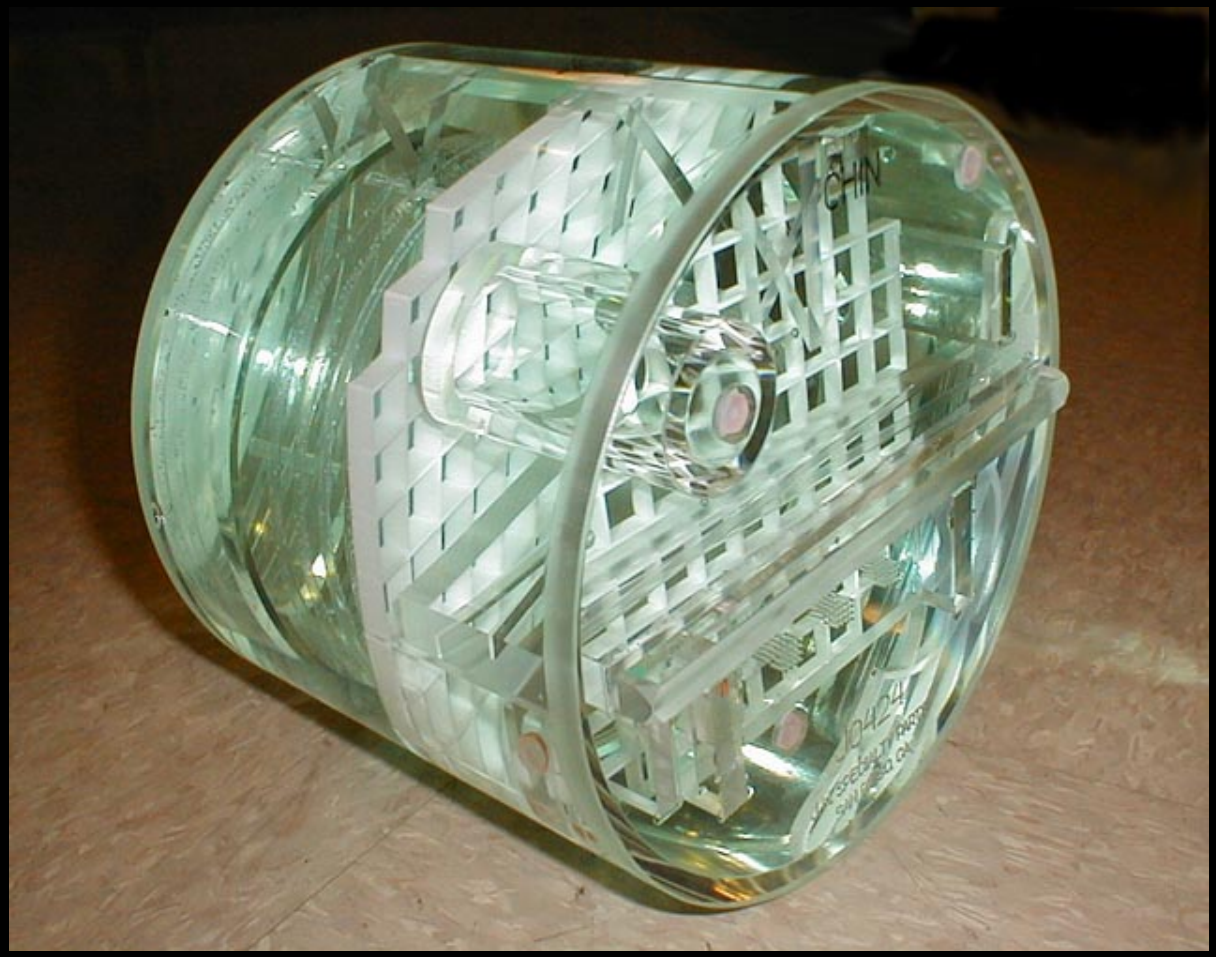
Brain for Suspected Demyelinating Disease* - maximum examination time ≤ 35 minutes

Required Sequences	Category A: Pulse Sequence and Image Contrast	Category C: Anatomic coverage and imaging planes *Failure to meet these specifications will result in failure.*	Category D: Spatial Resolution
Axial, sagittal or coronal dark fluid	Must have good discrimination between the brain and CSF	• Axial must cover convexity to foramen magnum • Coronal must cover entire brain from anterior to posterior cranial vault • Sagittal must cover entire brain	Slice thickness ≤ 5.0 mm Gap ≤ 2.5 mm if coronal Gap ≤ 2.0 mm if axial In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.2 mm Pixel area ≤ 1.2 mm^2
Sagittal T2 FLAIR	Must have good water suppression The CSF must be hypo or isointense with the white matter	Sagittal must cover entire brain	Slice thickness ≤ 5.0 mm Gap ≤ 2.0 mm In plane pixel (read) ≤ 2.0 mm In plane pixel (phase) ≤ 2.0 mm Pixel area ≤ 2.0 mm^2
Axial T2 FLAIR	Must have good water suppression The CSF must be hypo or isointense with the white matter	Axial must cover from convexity to foramen magnum	Slice thickness ≤ 5.0 mm Gap ≤ 2.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.2 mm Pixel area ≤ 1.2 mm^2
Axial bright fluid	The CSF must be hyperintense relative to the brain Must have good contrast between the gray matter and white matter	Axial must cover from convexity to foramen magnum	Slice thickness ≤ 5.0 mm Gap ≤ 2.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.2 mm Pixel area ≤ 1.2 mm^2
Axial or coronal dark fluid post contrast	Must have good discrimination between the brain and CSF	• Axial must cover from convexity to foramen magnum • Coronal must cover entire brain from anterior to posterior cranial vault	Slice thickness ≤ 5.0 mm Gap ≤ 2.0 mm In plane pixel (read) ≤ 1.0 mm In plane pixel (phase) ≤ 1.2 mm Pixel area ≤ 1.2 mm^2

clinical images

- all images (clinical & phantom) must be submitted by the due date on the labels sent by the ACR
- each of the 4 image types are labeled and placed in film jackets with completed parameter data form
  - pulse sequence
  - FOV
  - acquired matrix
  - slice thickness
  - slice gap
- electronic submission
  - 2 CDROMS with embedded viewer

quantitative phantom testing



MRI accreditation phantom

- specific ACR MRI accreditation phantom is used
- specific protocols for T1 and T2 are provided in the site instructions with the full application
  - phantom site scanning instructions at www.acr.org
- each site is required to submit phantom images using the ACR protocol
  - *and* phantom images using its own routine T1 and T2 weighted scan protocol for head examinations
- same phantom images for all modalities on full-sized magnet
  - smaller phantom used for extremity-only magnets

phantom image submission - films & data required

- films
  - 12-on-1 films of all 4 series
- data
  - Dicom PC CD-ROM
    - preferred method
    - each series in separate directory
    - make certain data are easily located
    - make certain images are accessible by Osiris software
      - do <u>not</u> use embedded viewer
      - do <u>not</u> use compressed images
  - site archive format (tape or disk) is no longer acceptable

phantom image data

- **conversion of media to Dicom PC CD-ROM**
  - **provided by some manufacturers**
    - **Fonar**

DESACC

MEDICAL IMAGING SERVICE BUREAU

ACR MR Accreditation Applicants

Data Submission Instructions for Conversion of Phantom Data to CD-ROM

Submit Order To:

DesAcc, Inc.
ACR MR Accreditation, 2nd Floor
801 W. Adams Street
Chicago, IL 60607

YOUR RETURN SHIPPING ADDRESS:

To avoid delay please follow the instructions below:

Please allow two weeks for the data conversion to be completed.

1. **Use one form** for each disk submitted

2. **Write your MRAP Number** (Site No.) including the **Unit No.**, (XXXXX Unit XX) or affix your MRAP barcode sticker to the upper right corner of your **Phantom Data Sheet** (Site Scanning Data Form).

3. **Label the media** with your institution and MRAP No. **One scanner per disk.** Phantom data only, no clinical or patient data needed.

4. **Send your media**, a photocopy of your **Phantom Data Sheet**, your **payment** and this **completed form** (one form per disk) to DesAcc via FedEx, UPS or DHL (if shipping 12" media, please insure the shipment).

5. **DesAcc will send back to you** your original media and a CD-ROM containing your data. The data has been converted into DICOM for standardization purposes, and includes an HTML version viewable with any www browser. Follow the instructions on the back of your CD-ROM case to view your dataset.

Contact Name _____ **MRAP No.** _____ **Unit No.** _____

Site Name for CD Label _____

Phone _____ **FAX** _____ **E-mail** _____

Scanner Manufacturer _____ **Scanner Type** _____

Order Information	*5 1/4"MOD, DAT, CD or DVD*	*12"MOD*	*Total*
Media Conversion Charge[1]	$200 per disk	$250 per disk	
Additional CD's[2]	$25 each	$25 each	
		IL Sales Tax[3] *(6.00% for non-exempt Illinois organizations only)*	IL Only
		Shipping Charge[4] *(additional charges apply for more than 1 disk)*	$25.00
		Calculate the Total Charges Here:	

[1] Price includes one CD that you will submit to the ACR.

[2] If you would like a duplicate CD for your records.

[3] If you are an Illinois customer and your facility is exempt from sales tax, please include a certificate of status and an exemption number with your order
E _____

[4] We send our packages via DHL.

DesAcc expressly excludes liability for any indirect, specific, incidental or consequential loss or damage, or loss of profit, business or revenue, which may arise in respect of this service. Your exclusive remedy and DesAcc's entire liability shall be limited to the total cost of this service agreement.

I accept these terms and authorize DesAcc to fulfill this order:

AUTHORIZED SIGNATURE

Acceptable forms of Payment are Check or Credit Card:

☐ Check enclosed ☐ Charge the proper amount to my credit card:

☐ AMEX ☐ VISA ☐ DISCOVER ☐ MC

Security Code

Card Number

Expiration Date

Authorized Signature *(name as it appears on card)*

Date Signed

DesAcc, Inc. • 801 W. Adams St. • Chicago IL 60607
Phone: 312-930-5617 - Fax 312-930-5618 - E-mail: mracreditation@desacc.com - HTTP://www.desacc.com

Version 1.06

  - **available on newer workstations / PACS environments**
    - **make certain images on CD can be located & opened by Osiris**
  - **provided by DesAcc, Inc.**
    - **HTML format on CD-ROM available for**
      - **Elscint (5¼")**
      - **GE (most 5¼" & most DAT)**
      - **Hitachi (5¼")**
      - **Philips (5¼" & 12")**
      - **Siemens (5¼" & 12")**
      - **Toshiba (5¼")**
    - **$200-250 + $25 shipping**
    - **~ 2-3 weeks turnaround**
    - **http://www.desacc.com**
    - **312 930-5617**

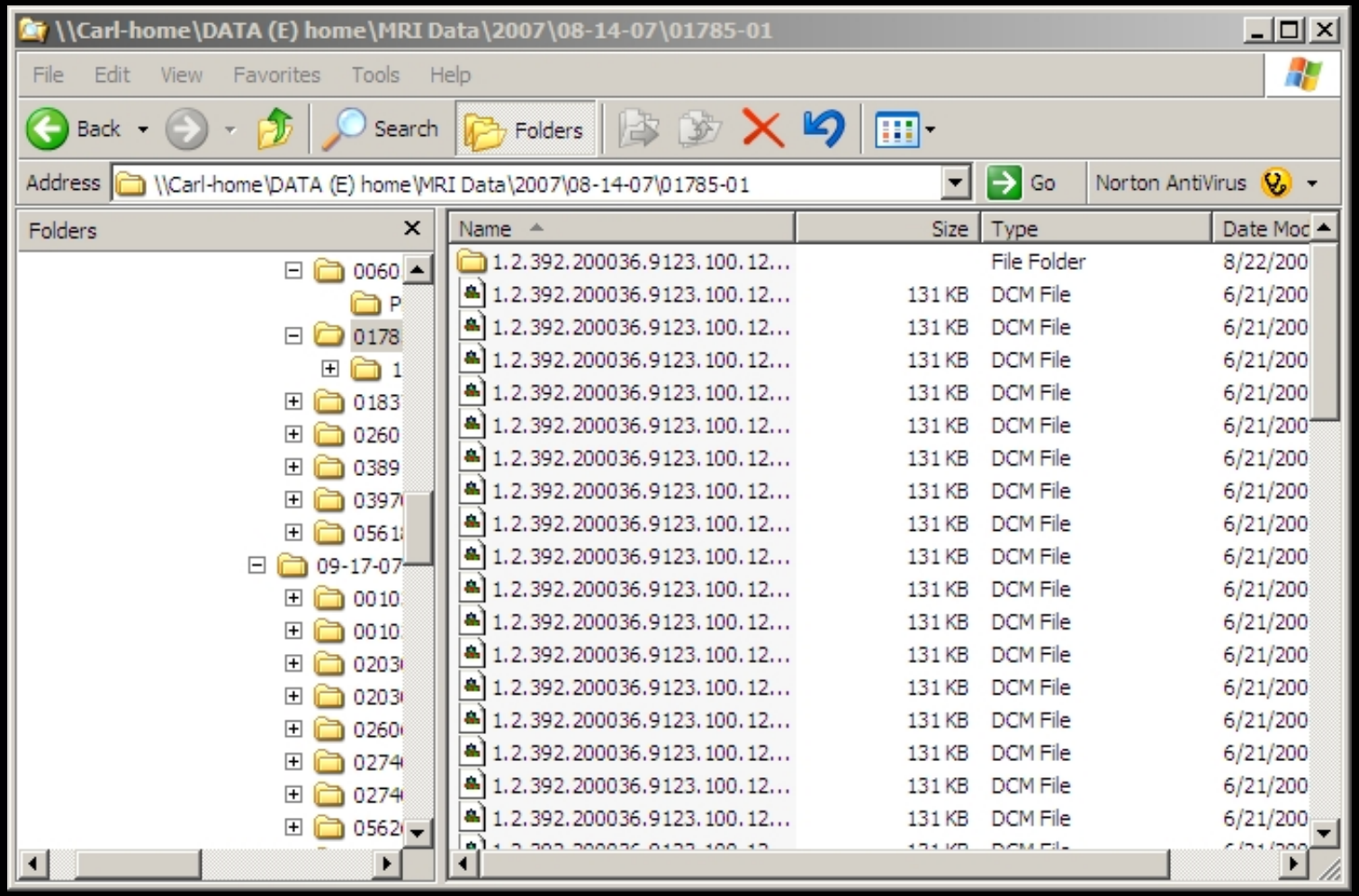
phantom image data – CD-ROM

- available on newer workstations / PACS environments
- DICOM only CD
  - with DICOMDIR
- MRAP applications as of Nov 2007:
  - 8798 units
  - 6052 facilities
- label CD

- MRAP accredited as of May 2010
  - 5437 facilities
  - 431 facilities under review
- ICAMRL accredited as of May 2010
  - 268 facilities

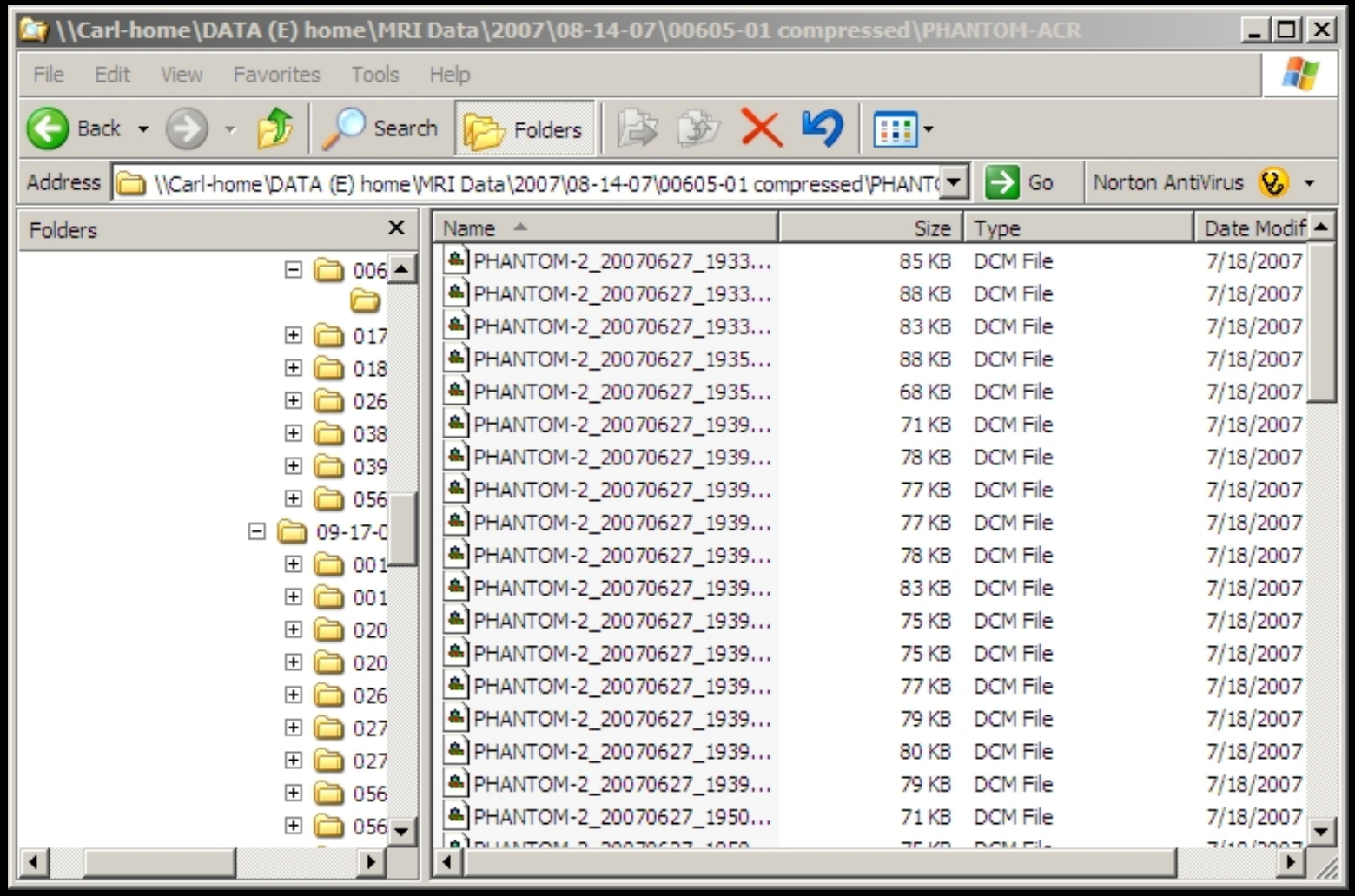
phantom data CD-ROM

- **uncompressed DICOM images**
  - **256 x 256 x 2 = 131072 bytes**



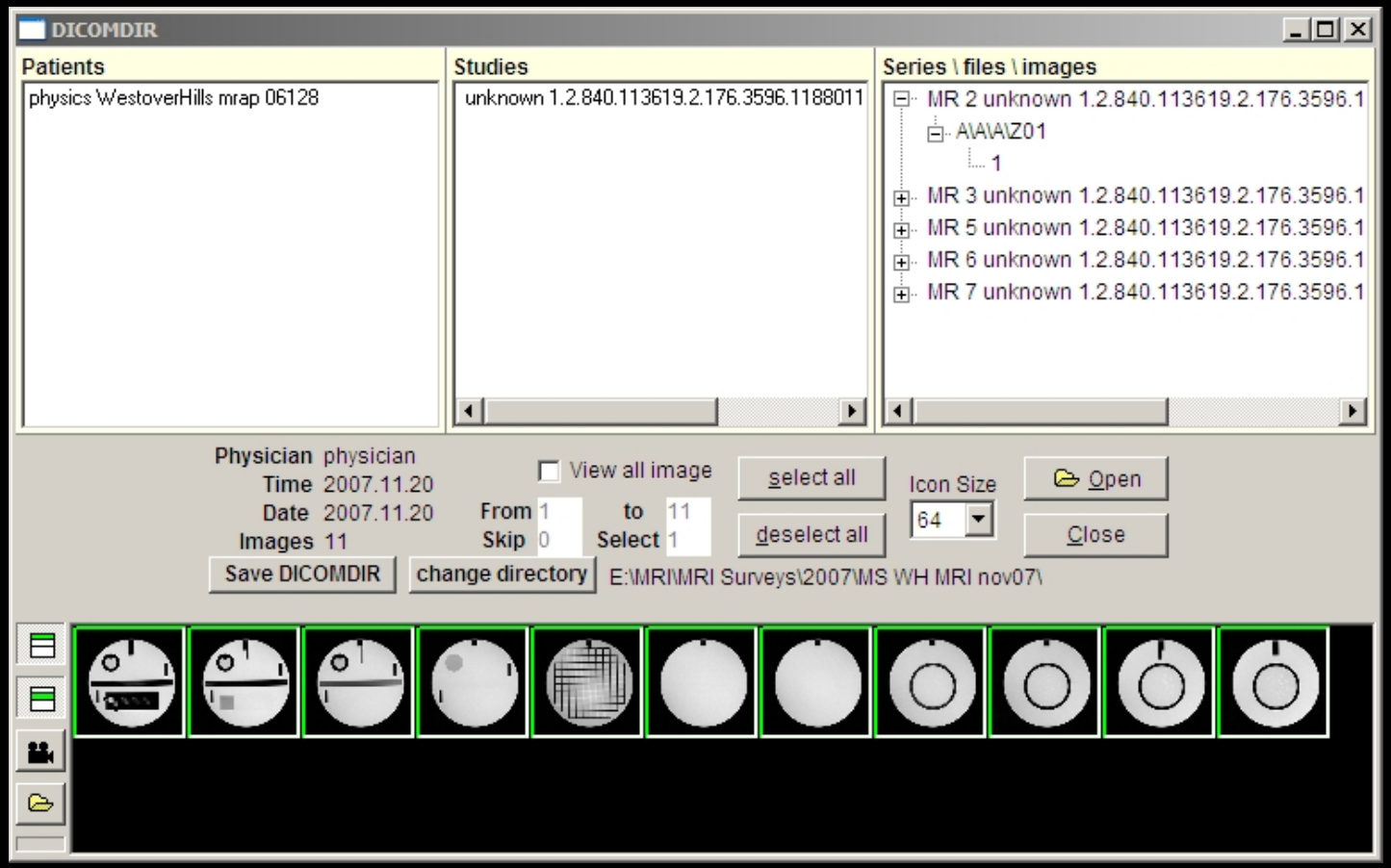
phantom data CD-ROM

- **embedded readers often compress images**



Osiris 4.19

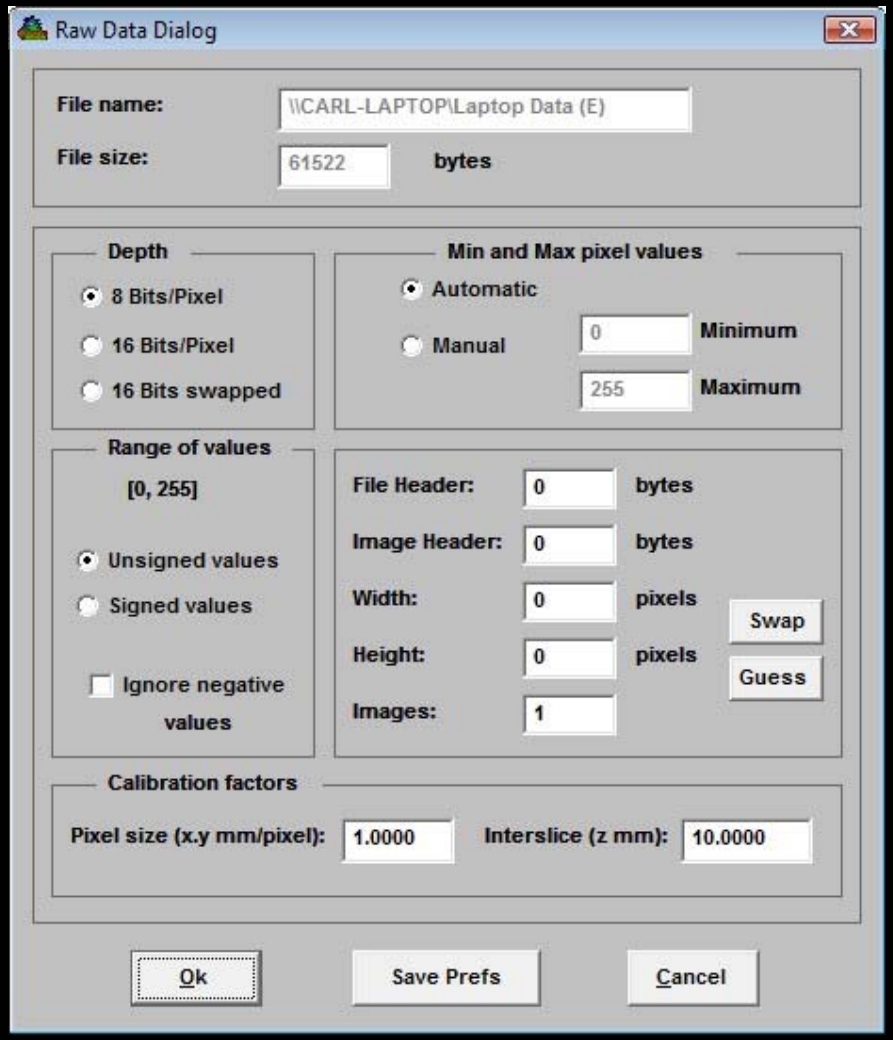
- free DICOM viewer
- used by ACR reviewers
- download at
  http://www.sim.hcuge.ch/osiris/01_Osiris_Presentation_EN.htm
- make certain Osiris can open images



make certain Osiris can open .dcm files

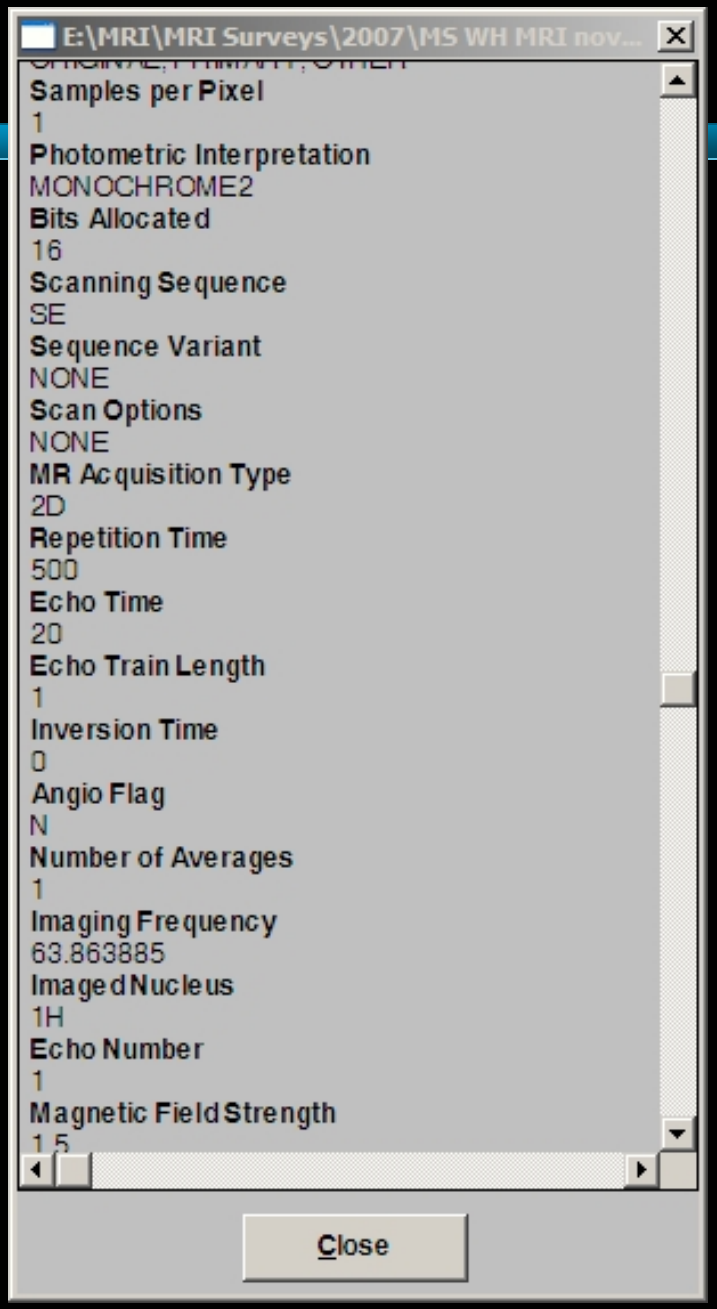
- Osiris correctly opens
  - uncompressed DICOM files

- Osiris may not open
  - compressed files
    - note: 61kB vs 131 kB
  - nonDICOM files
  - proprietary files



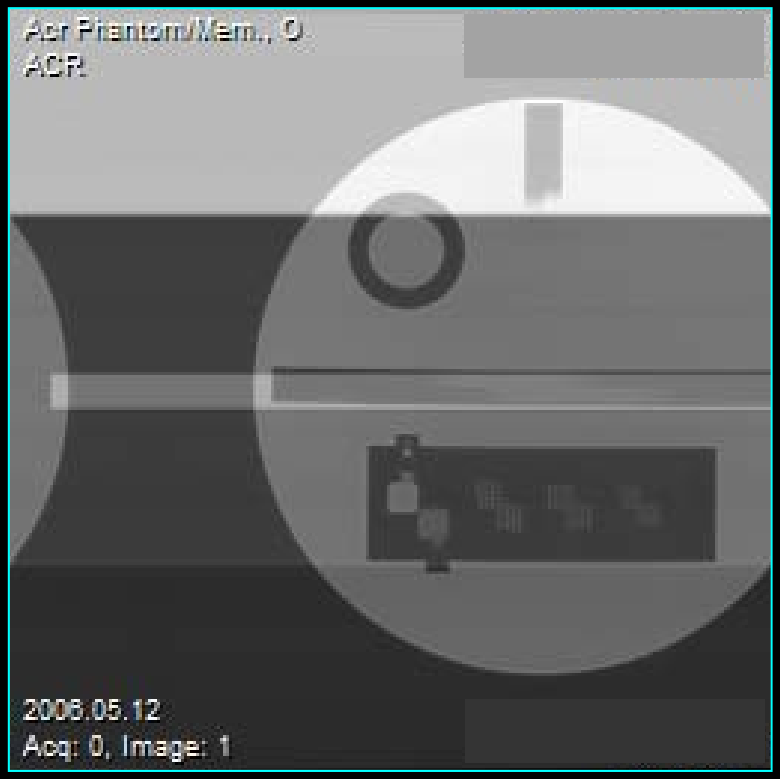
Osiris 4.19

- **check:**
  - navigation through images
  - window & level work
  - zoom
  - ROIs
  - DICOM headers
- **make certain Osiris does not crash with your data**
- **most consoles produce good CD-ROMs**
  - GE
  - Siemens
  - Philips
  - Toshiba
  - Fonar ?
  - Hitachi ???
- **many PACS systems do not produce acceptable CD-ROMs**
  - proprietary and or compressed formats



check images before submitting

compressed image



wrong gap

electronic submission

ACR Accreditation System - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Address http://acredit.acr.org/Forms/TestingPackages/MRAP/PhantomSiteScanningLarge.aspx?TpFormId=34&TpId=3284&SelectedExamId=100807

Evaluation

- ✓ Clinical TID (Hepatobiliary)
- ✓ Clinical TID (Brain for suspected demyelinating disease)
- ✓ Clinical TID (Cervical Spine)
- ✓ Clinical TID (Forefoot)
- ✓ Clinical TID (Abdomen for renal artery stenosis)
- ✓ Phantom Site Scanning Data Form (Large Phantom)

Submit

- ✓ Upload Files
- ✗ Submit

Note

- ✓ Completed
- ✗ Not completed
- ✗ Not available
- ⓘ Information

1. MR Manufacturer: Siemens

2. Model Name: SYMPHONY

3. Serial Number: 23892

4. Year Manufactured: 2006

5. Magnetic Field Strength: 1.50T

6. Operating Location: Fixed

Pulse Sequence Acquisition Parameters

Fill in all parameters for both the ACR sequences and for your site's sequences.

		a	b	c	d	e	f	g	h	i	j	k	l
	Study	Pulse Sequence	TR (ms)	TE (ms)	FOV (cm)	Number of Slices	Slice Thickness (mm)	Slice Gap (mm)	NEX	Matrix		Routine Receive Band - Width (kHz)	Scan Time (min:sec)
7.	ACR Sagittal locator	Spin Echo	200	20	25	1	20	N/A	1	256	256		0:56
			200.00	20.0	25.00	1	20	N/A	1	256	256		0:53
8.	ACR Axial T1	Spin Echo	500	20	25	11	5	5	1	256	256		2:16
			500.00	20.0	25.00	11	5.0	5.0	1	256	256		2:10
9.	ACR Axial T2 Double-echo	Spin Echo	2000	20/80	25	11	5	5	1	256	256		8:56
			2000.0	20/80	25.00	11	5.0	5.0	1	256	256		8:36
10.	Perform Your Site's Axial T1-weighted Brain Scan	SE	500.00	17.00	Freq: 25.60	11	5	5					
					Phase: 18.7		5.00	5.0	2	256	208	130.0	3:30
11.	Perform Your Site's Axial T2-weighted Brain Scan	TSE	3000.00	113.00	Freq: 23.00	11	5	5					
					Phase: 18.70		5.00	5.0	2	384	312	130.0	2:09

12. Scan Options Used on the ACR Spin-echo T1- and T2-weighted Axial Scans: T1:se_20rb195 T2:se_20r

13. Scan Options Used on "Your Site's Axial T1- and T2-weighted Brain Scans": T1:FA= 80 T2:Turbo Fact

14. Serial Number of phantom used for testing: J6153

Date of Testing: 12 / 14 / 2009

Testing Performed by: JESUS A. PEREZ

Done

Start | Inbox - Microsoft Outl... | FUSION RIS - [Patient... | My Documents | ACR Accreditation Sy... | 07 AMI SS MRI phant... | 3:49 PM

continuing requirements of accreditation program

- weekly QC
- annual tests
- ACR has the right to perform random site and/or film inspections

quality control

- effective August 2002:
- weekly tests *(initially daily)*:
  - central frequency
  - transmitter gain /attenuation
  - geometric accuracy
  - spatial resolution
  - low-contrast detectablilty
  - image artifact assessment
- weekly:
  - laser film QC
  - visual checklist
- annual:
  - physicist/MR scientist performance evaluation & QC review

- effective July 2005:
- for renewal, site must send:
  - 3 months QC/printer data
  - annual survey report
    - dated within 12 months
    - documentation of corrections for failures
- QC and annual survey are now required for initial applications too

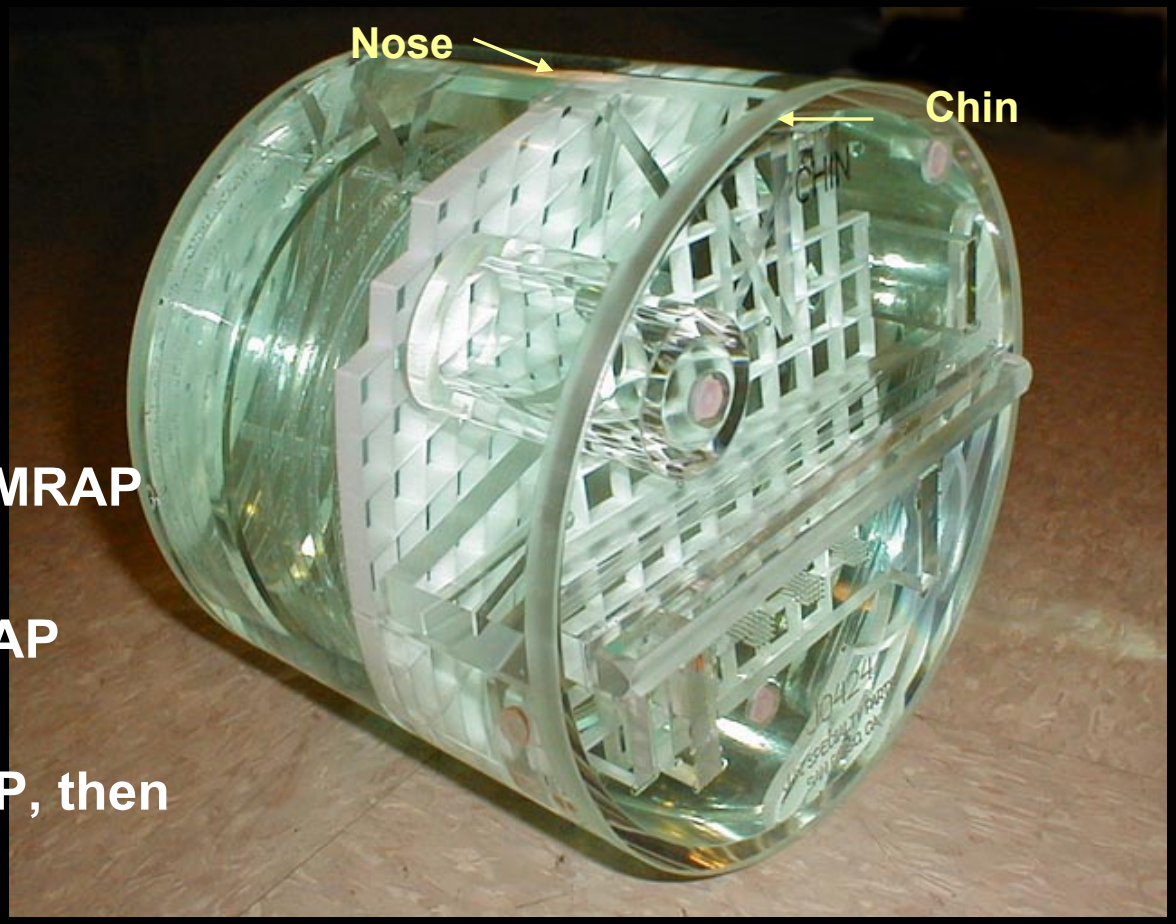
ACR MRI large phantom

- **J.M. Specialty Parts**

  11689-Q Sorrento Valley Road

  San Diego, CA 92121

  (858) 794-7200
- **$1050**
  - **previously $730**
- **delivery**
  - **6-8 weeks without MRAP number**
  - **2-3 weeks with MRAP number**
  - **order without MRAP, then call to add MRAP**



ACR MRI small phantom

- **J.M. Specialty Parts**

  11689-Q Sorrento Valley Road

  San Diego, CA 92121

  (858) 794-7200

- **$780**

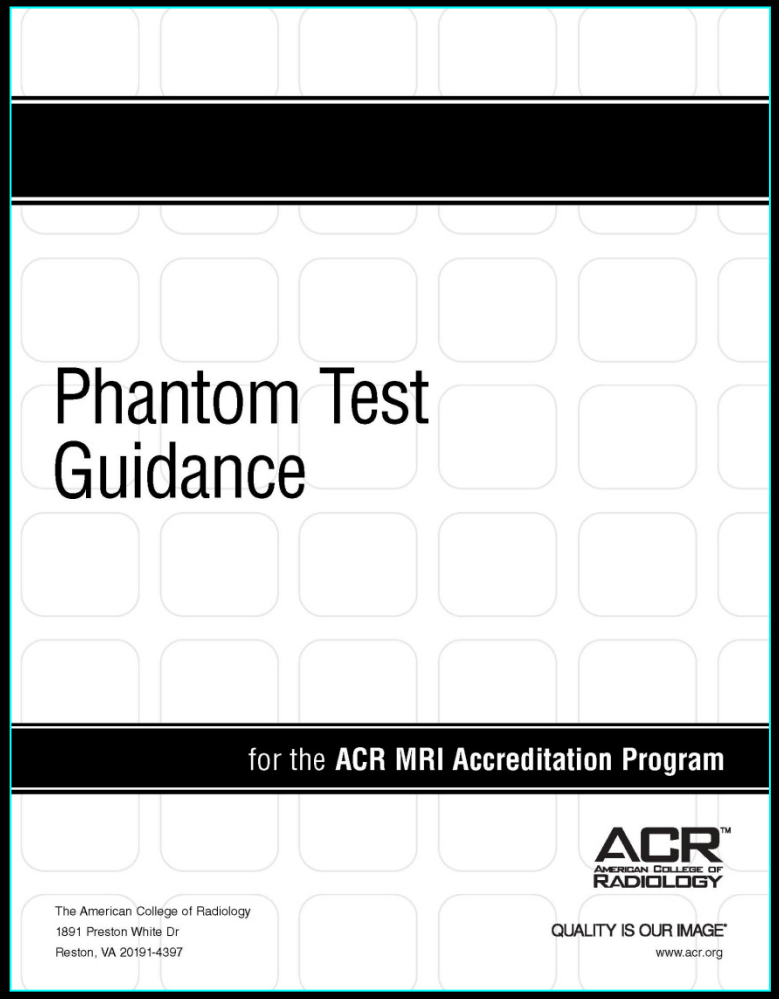
performance criteria

- ***Phantom Test Guidance for the ACR MRI Accreditation Program***
  - **describes tests**
  - **instructions**
  - **performance criteria**
  - **reasons for failure**
  - **available from www.acr.org**
  - **"large phantom" = old phantom**

Phantom Test Guidance for Use
of the Small MRI Phantom
for the

ACR AMERICAN COLLEGE OF RADIOLOGY

MRI
Accreditation
Program



Phantom Test Guidance

for the ACR MRI Accreditation Program

ACR™ AMERICAN COLLEGE OF RADIOLOGY

The American College of Radiology
1891 Preston White Dr
Reston, VA 20191-4397

QUALITY IS OUR IMAGE®
www.acr.org

site scanning instructions

- ***Site Scanning Instructions for use of the MRI Phantom for the ACR MRI Accreditation Program***
  - **phantom positioning**
  - **pulse sequences**
  - **film and data instructions**
  - **sent to site with full application**
  - **available from ACR**

phantom pulse sequences

- 2 ACR sequences
  - T1
  - T2
- identical for all sites
- extremity-only sites use different ACR sequences for small phantom

- 2 site sequences
  - T1
  - T2
- site specific
  - may be used to increase SNR in order to pass low-contrast tests on low-field units

ACR sequences

regular phantom

- 1 sagittal localizer slice
  - T1: SE
  - TR=200 ms, TE=20ms
  - 25 cm FOV, 256x256, 20mm slice
  - 1 NEX (NSA, NAQ, AVE)
- 2 sets of 11 axial slices
  - 25 cm FOV, 256x256
  - 1mm pixels
  - 5 mm slice, 5 mm gap
  - 1 NEX (NSA, NAQ, AVE)
  - T1:
    - SE, TR=500 ms, TE=20 ms
  - T2:
    - SE, TR=2000 ms, TE=20/80 ms
    - Use 2nd echo only
- all sites must use the same ACR sequences
  - slight modifications allowed if scanner cannot set them
    - T1: SE, TR=515 ms, TE=20 ms (Toshiba Opart)
    - T2: SE, TR=500 ms, TE=90/25 ms (Fonar)
  - document other scan parameters on site data sheet

small phantom

- 1 sagittal localizer slice
  - T1: SE
  - TR=200 ms, TE=__ms
  - 12 cm FOV, 192x152, 20mm slice
  - 1 NEX (NSA, NAQ, AVE)
- 2 sets of 7 axial slices
  - 12 cm FOV, 192x152
  - 0.625mm x 0.79mm pixels
  - 5 mm slice, 3 mm gap
  - 1 NEX (NSA, NAQ, AVE)
  - T1:
    - SE, TR=500 ms, TE=20 ms
  - T2:
    - SE, TR=2000 ms, TE=20 ms
    - only 1 echo

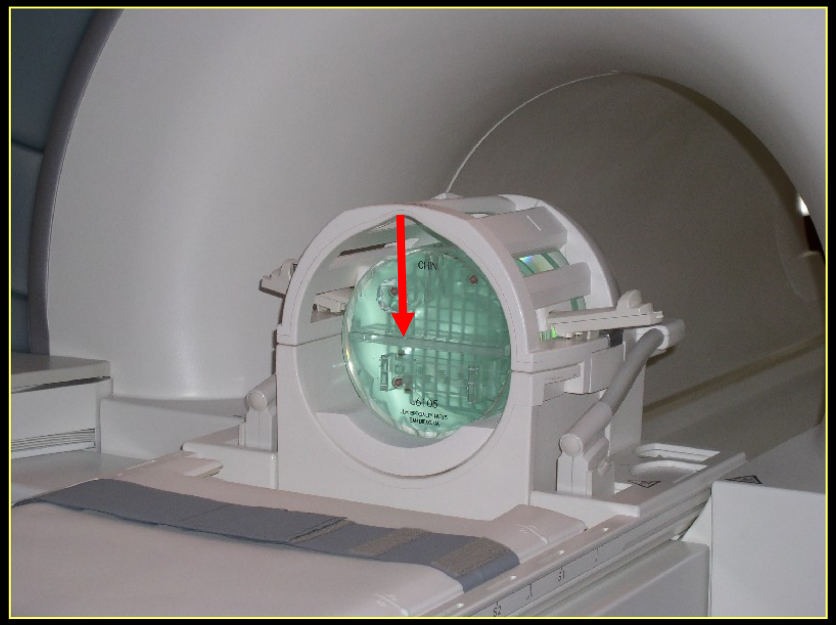
required phantom tests

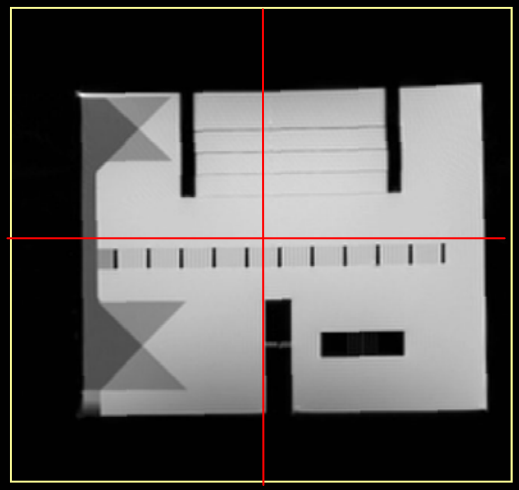
- geometric accuracy
- high-contrast spatial resolution
- slice thickness accuracy
- slice position accuracy
- image intensity uniformity
- percent signal ghosting
- low-contrast object detectability
- image artifacts

alignment of ACR phantom

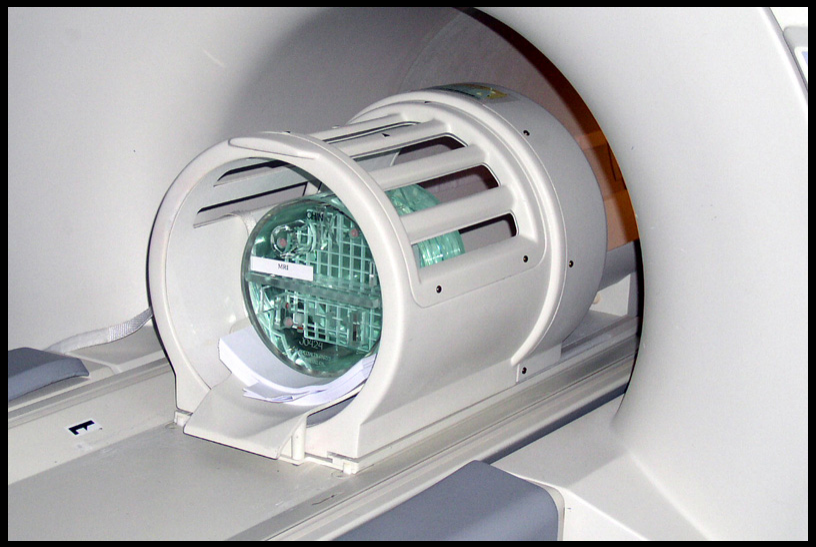
pre-scanning procedures

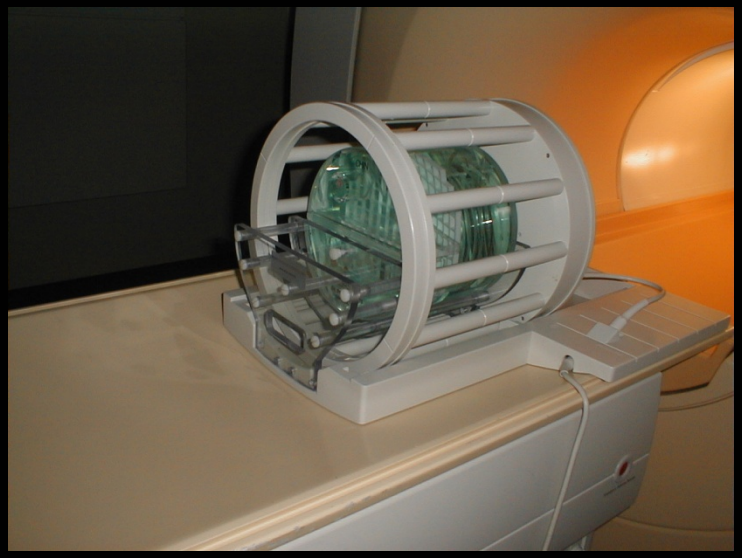
- magnet should be checked by service engineer prior to acquisition
- alignment is important
  - center of head coil
    - computer paper
  - straight
    - use bubble level
  - centered SI, LR & AP
  - make localizer slice in all 3 planes
  - use grid to check centering
  - record position for future use



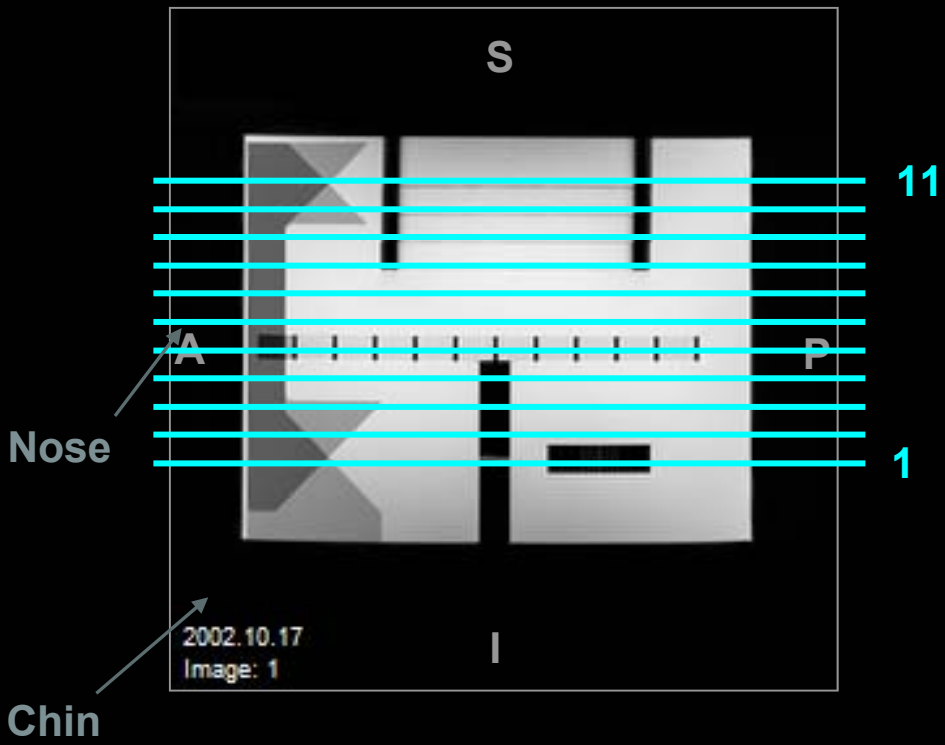


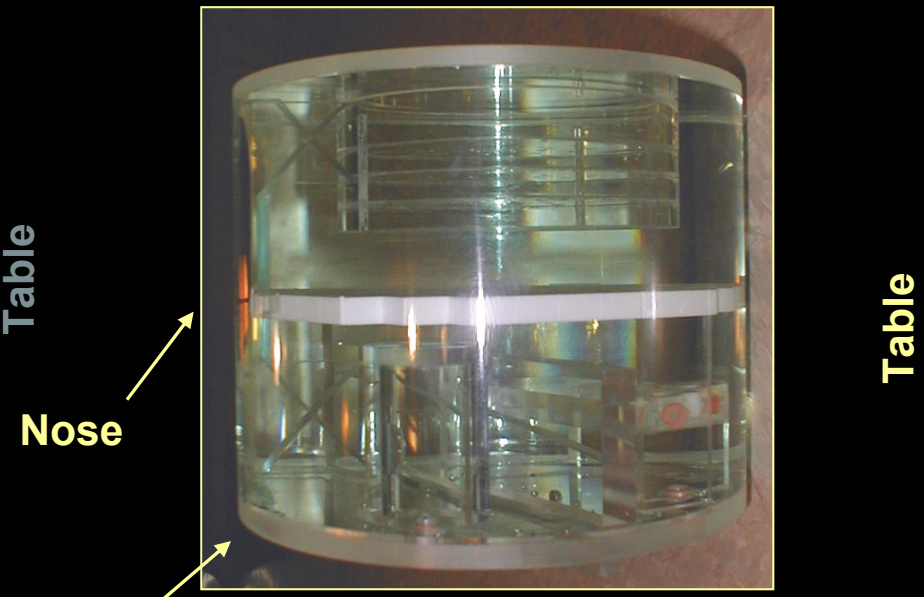
alignment of ACR phantom





sagittal localizer slice

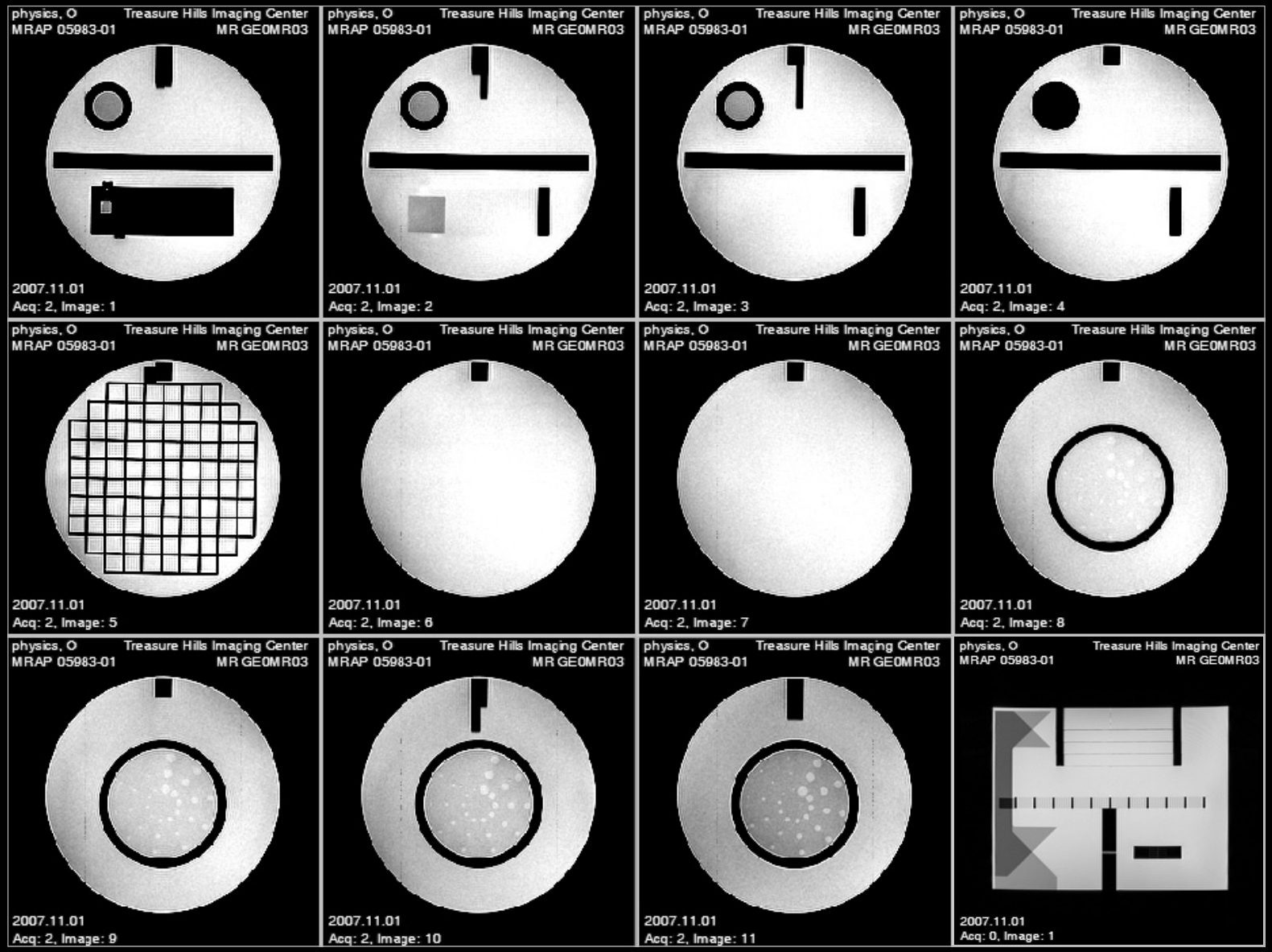




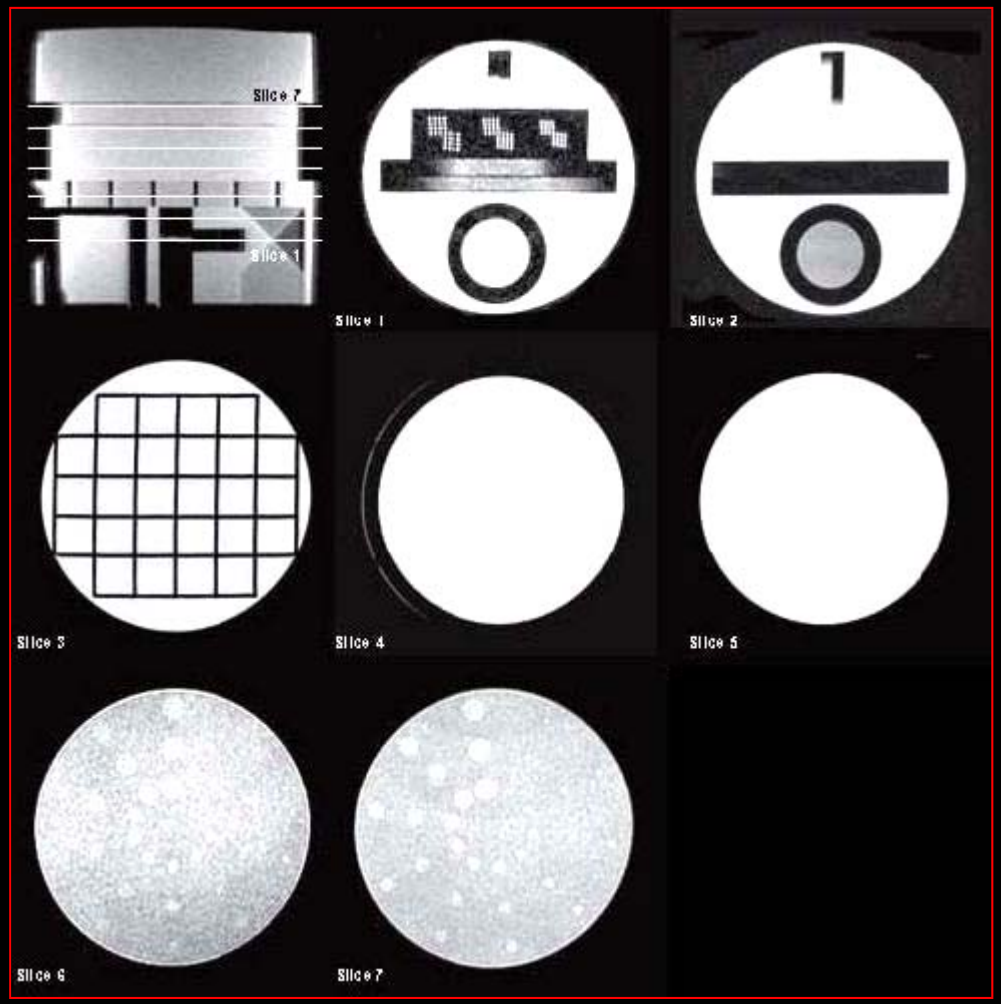
sagittal localizer slice

- set up 11 axial slices for all 4 series
  - 5 mm thick with 5 mm gap
    - small phantom : 7 axial slices, 5 mm slice, 3 mm gap
- notes
  - if geometric accuracy is off, low contrast slices 8-11 may not be accurate
  - phantom wedges and LCD insert 11 may not be perfectly aligned
  - some units have protocols which number slices opposite of the ACR recommendations
  - may not start renumbering at "1" for each series
  - make note of which image is 2nd echo on T2

11 axial slices & localizer



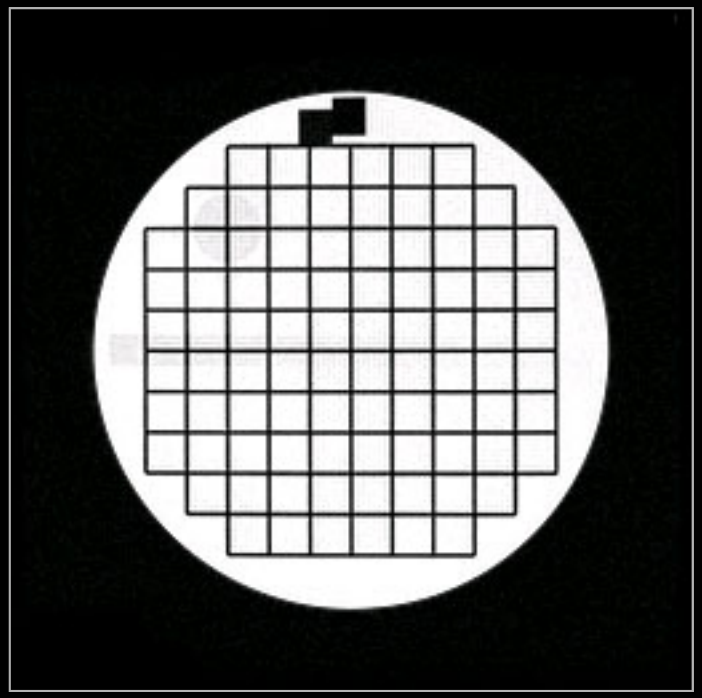
7 axial slices & localizer on small phantom



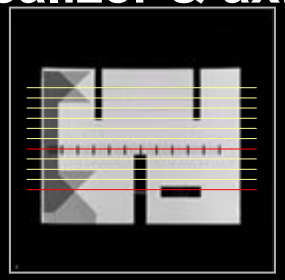
geometric accuracy

- sagittal localizer & ACR axial T1 slices 1 & 5
  - specific window & level:
  - window as narrow as possible
  - set level where ½ of water is dark (mean)
  - set window <u>width</u> = <u>mean</u> value

    & window <u>level</u> = <u>½ mean</u> value

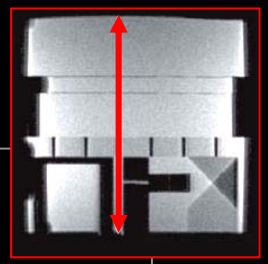


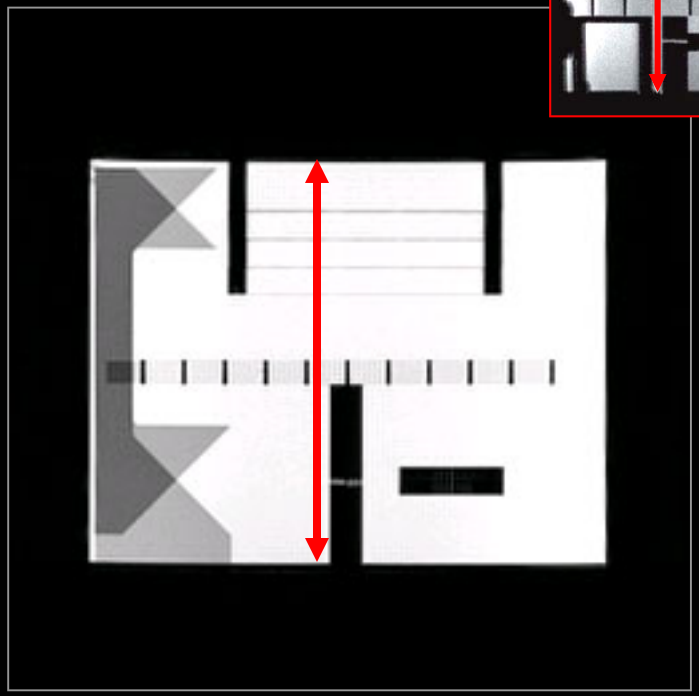
  - window/level must be set separately for localizer & axial T1
    - both axial slices use same window/level
  - small phantom
    - sagittal localizer & ACR axial slices 1 & 3



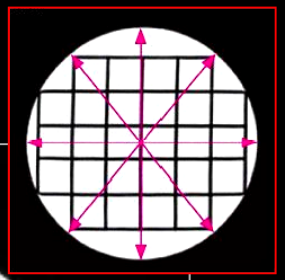
geometric accuracy - measurements

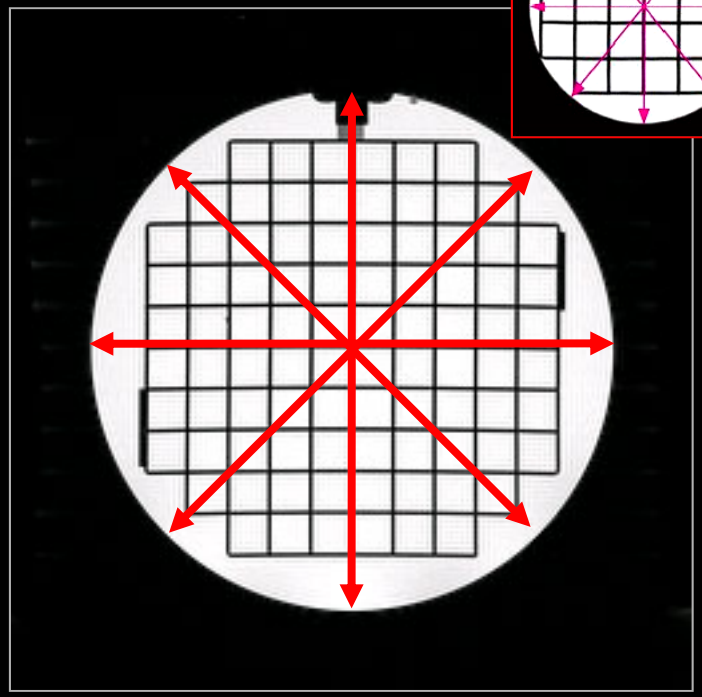
- sagittal localizer
  - top-bottom (z)
  - 148 mm
  - small phantom = 100 mm
- action limits
  - ± 2 mm





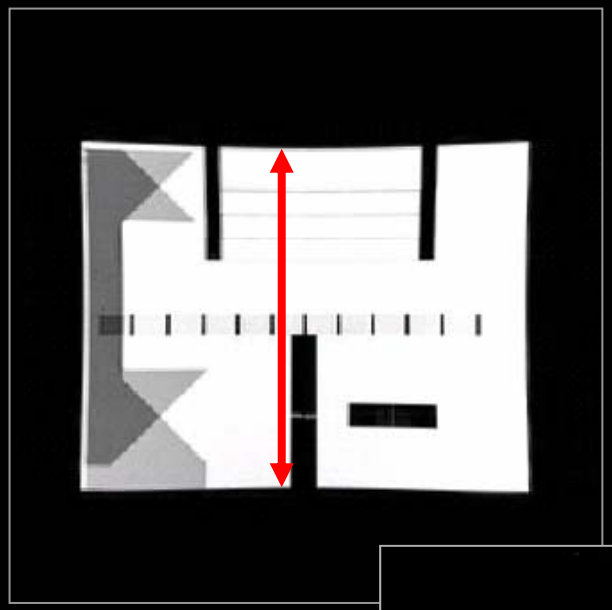
- slice 1 & 5 of ACR axial T1
  - horizontal & vertical (x & y)
  - diagonal on slice 5 (3 for small)
  - 190 mm
  - small phantom = 100 mm
  - different W/L than localizer
- action limits
  - ± 2 mm

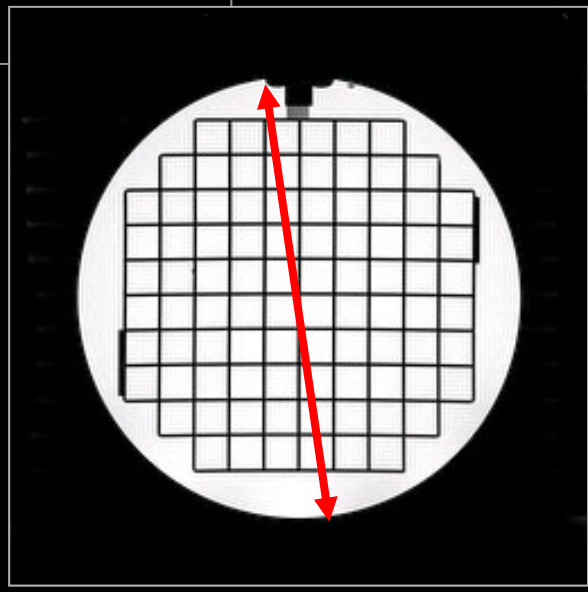




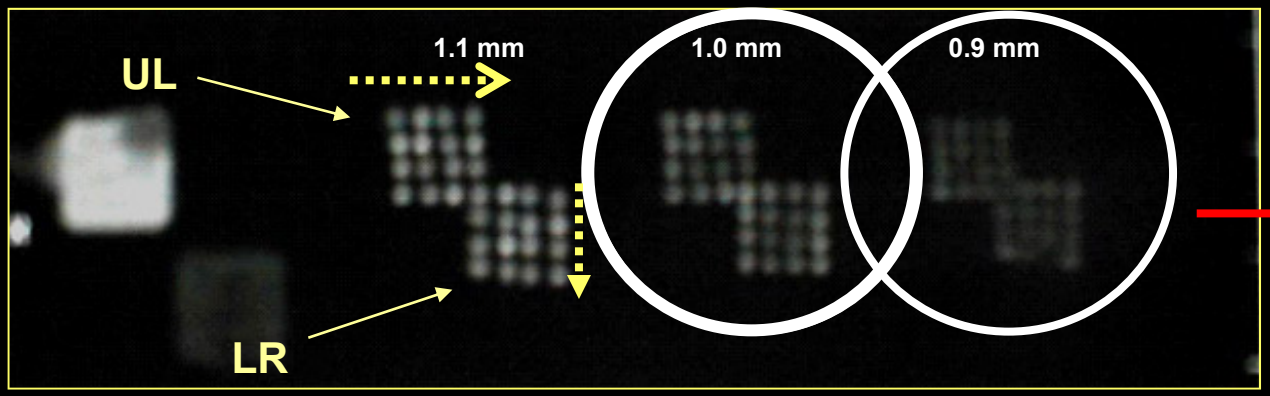
geometric accuracy - notes

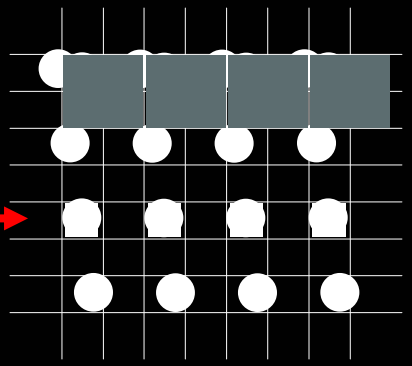
- image may be bowed
  - accurate at one location, inaccurate at another
  - measure in the center
- bubble may obscure top of slice
  - measure at angle
- localizer & axial slices need different W/L
- operator may know the actual values and aim for them
- open short bore magnets may use geometric corrections
  - Siemens – Large FOV or 2D distortion correction





high-contrast spatial resolution

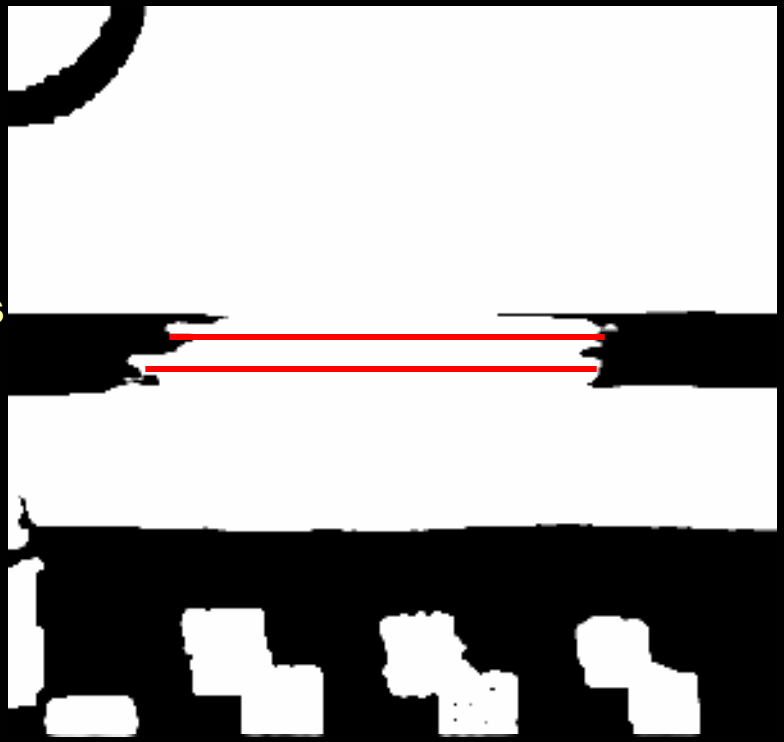




- **measurements**
  - use slice 1 of ACR T1 & ACR T2
  - magnify slice 1 by 2 to 4
  - observe UL holes ; adjust window/level
    - observe <u>rows</u>: if all 4 holes in a <u>single</u> row are distinguishable, score image as resolved at this hole size
    - view all three sets (1.1 mm, 1.0 mm, 0.9 mm)
    - score = smallest holes resolved
  - repeat for LR array with <u>columns</u> of holes
- **performance criteria: 1.0 mm**
- **small phantom**
  - 0.9 mm, 0.8 mm, 0.7 mm sets
  - pixel size = 0.625 x 0.79 mm
  - performance criteria: 0.8 mm

slice thickness accuracy

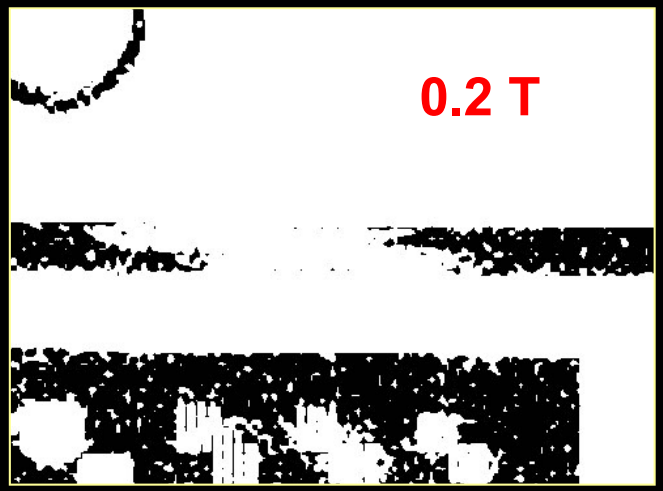
- **slice 1 of ACR T1 & ACR T2**
  - crossed ramps (10:1 slope)
  - measure mean
    - magnify by 2 to 4
    - adjust window/level to see signal ramps
    - 2 ROIs
    - mean of middle of each signal ramp
    - take average
  - measure width
    - lower level to ½ average
    - set window at <u>minimum</u>
    - measure lengths of top and bottom ramps
  - calculate slice thickness
  - performance criteria:
    - 5.0 ± 0.7 mm



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

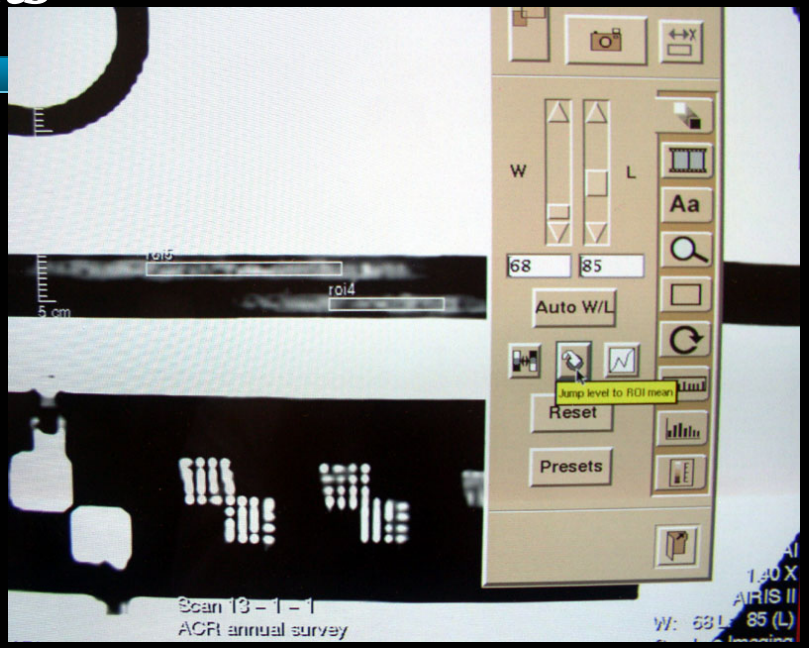
slice thickness - notes

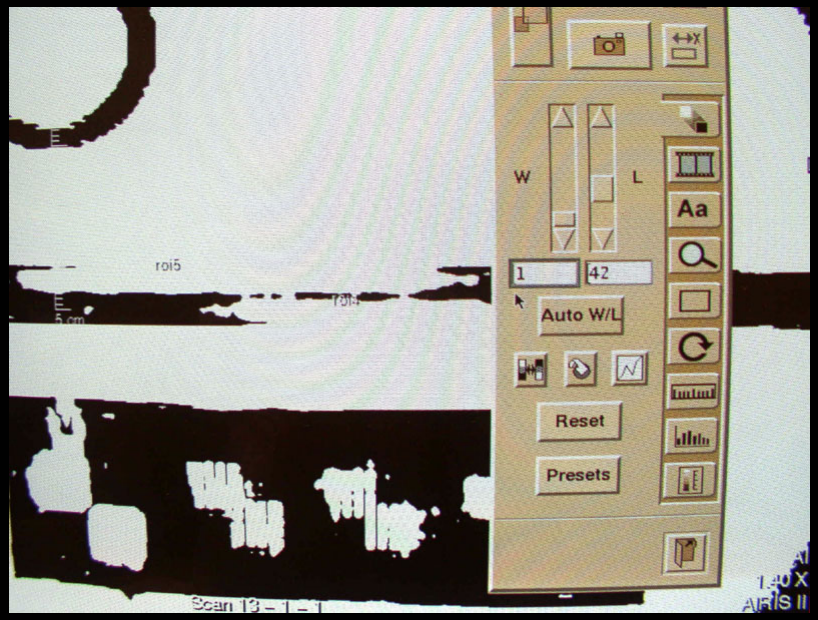
- edges of ramps difficult to determine
  - Gibbs artifacts
  - noise (low field magnets)
- display may give max-min signal (or use relative scale)
  - use Osiris
- 1 mm measurement error = 1/10 mm error in slice thickness
- same for small phantom



slice thicknesses measurements

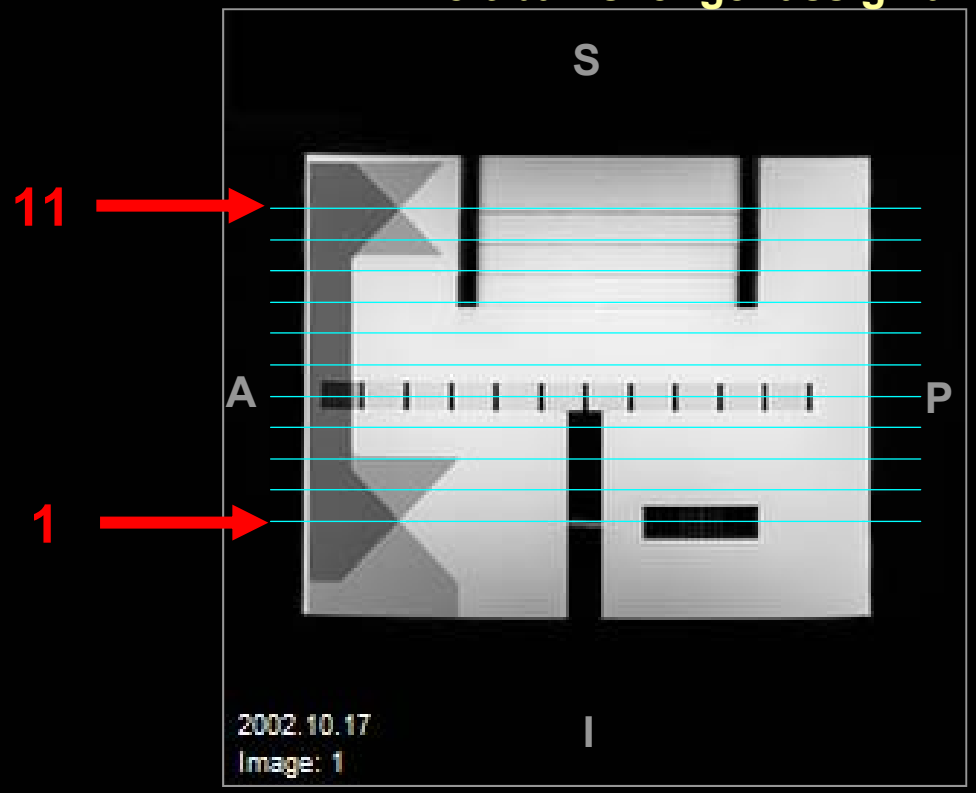
- **Hitachi Airis II**
  - **ROI scale different than WL scale**
  - **"Jump level to ROI mean"**
    - **sets level to mean of ROI**
    - **displays mean using WL scale**
    - **manually reduce level to ½**
    - **manually reduce width to 1**
- **Toshiba Opart & Vantage**
  - **ROI scale different than WL scale**
  - **no simple workaround**
  - **burn CD**
    - **use Osiris or Osirix**

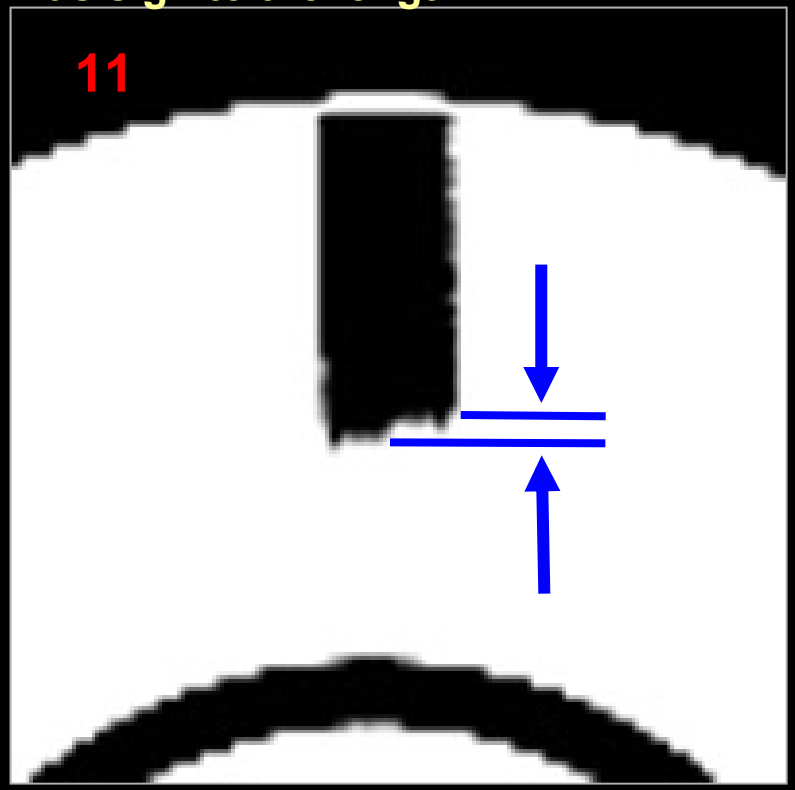




slice position accuracy

- **measurements**
  - **use slices 1 & 11 of ACR T1 & ACR T2**
    - **only slice 1 of small phantom**
  - **magnify by 2 to 4 & adjust window/level**
  - **measure difference of left & right bars**
    - **if left bar is longer assign a minus sign to the length**





slice position accuracy

- **performance criteria:**
  - **magnitude of bar length difference ≤ 5 mm.**
    - **actual displacement is 1/2 of the measured difference (wedges have 45° slopes)**
    - **operator may strive for more precision than is necessary**
    - **phantom wedges & disks may not be perfectly aligned**
    - **small phantom**
      - **slice 1 only**

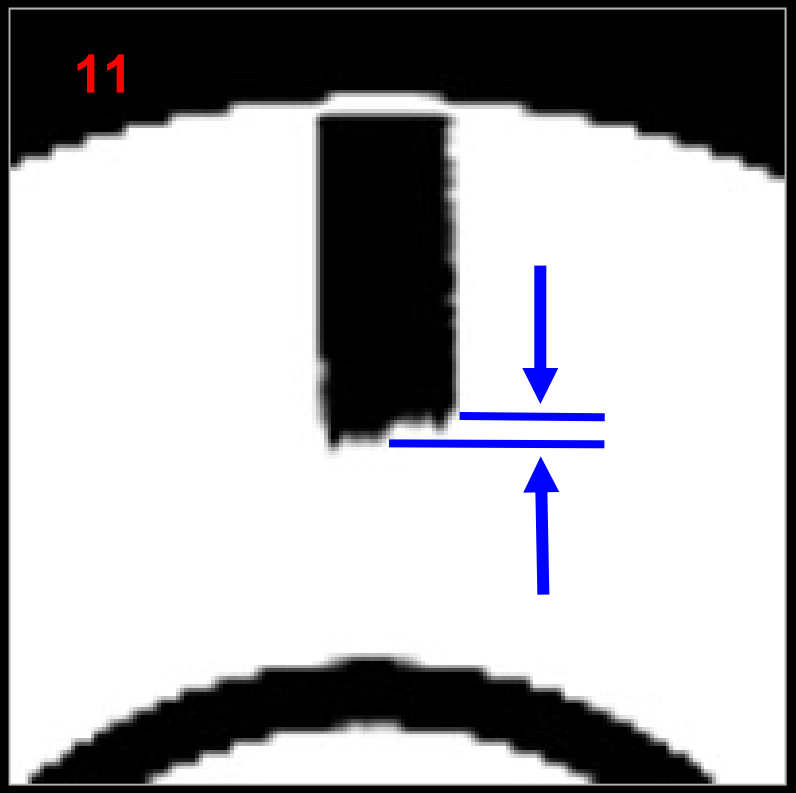
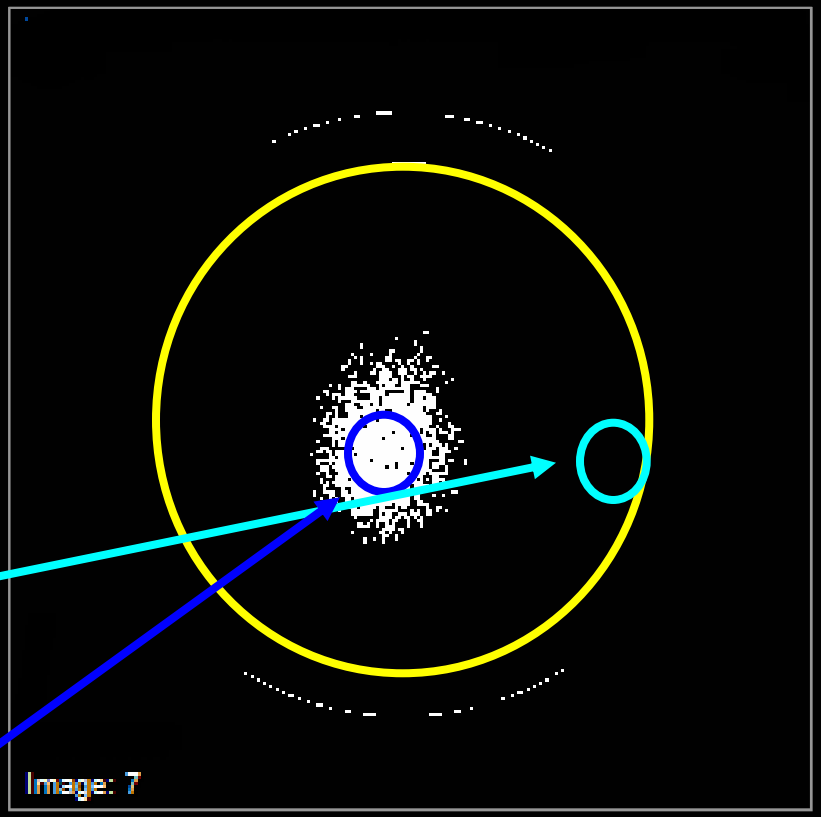


image intensity uniformity

- **slice 7 of ACR T1 & T2**
  - **make large ROI (195-205 cm²)**
    - **small phantom: 54-56 cm² on slice 4**
  - **low-signal region:**
    - **set window width to minimum**
    - **lower level until entire ROI is white**
    - **raise level until 1 cm² region of black appears**
    - **use 1 cm² ROI to record mean of this low-signal region**
  - **high-signal region:**
    - **raise level until only 1 cm² region of white remains**
    - **use 1 cm² ROI to record mean of this high-signal region**



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

image intensity uniformity

- **performance criteria:**

  PIU ≥ 87.5%

  - **if there is not a well-defined high/low intensity level… …..uniformity is very high!**

  - **same for small phantom**

- **for 3.0T:**

  PIU ≥ 82% ***(July 2005)***

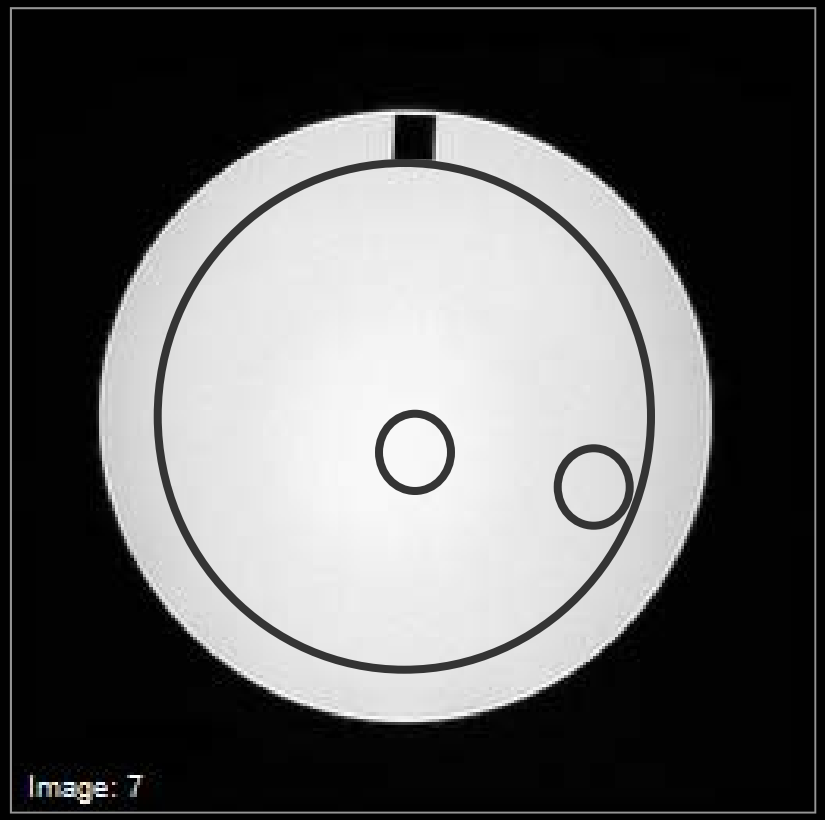


image intensity uniformity – 8-channel coils

- *smaller coil*
  - *harder to setup*
  - *poorer uniformity*
- *corrections*
  - *Surface Coil Intensity Correction (SCIC) – GE*

Transmitter Gain	Mean SNR	Uniformity
114	483.9	84.67%
117	188.9	93.19%

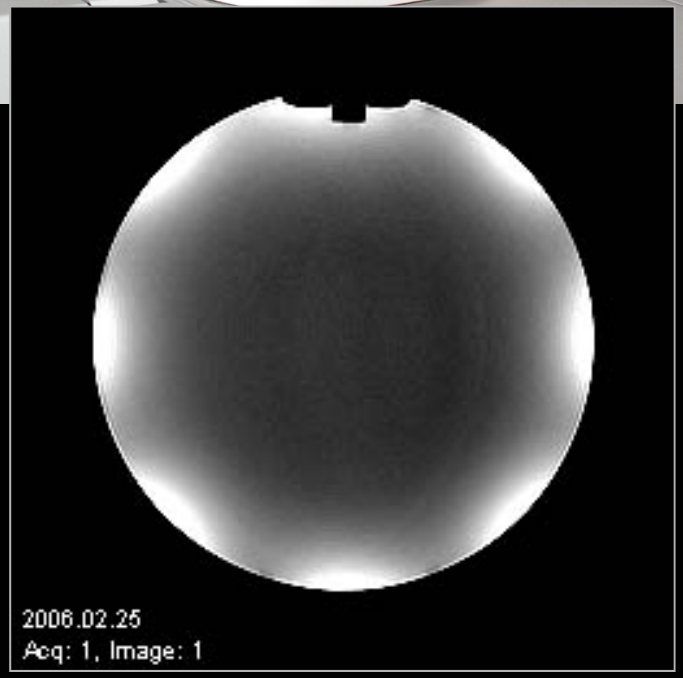
no correction

SCIC

  - *Prescan Normalization (Siemens)*
  - *"CLEAR"*

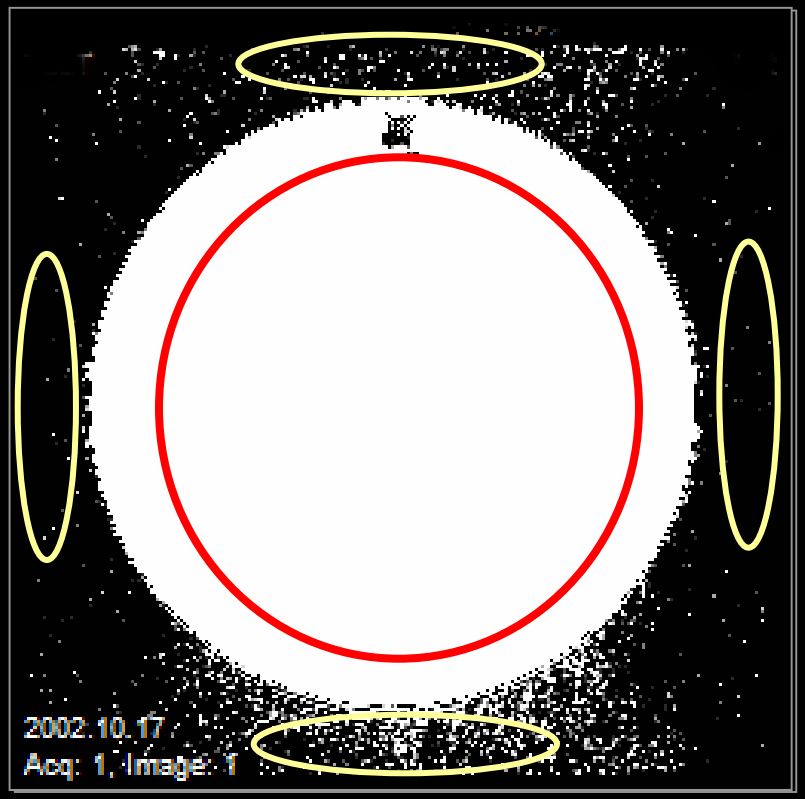
    (Philips)

    "Quadrature" vs "SENSE"



percent signal ghosting

- **use slice 7 of ACR T1**
  - **make large ROI (195-205 cm²)***
    - **record mean**
    - **small phantom: 54-56 cm² on slice 4**
  - **make 4 elliptical ROIs**
    - **10 cm² with 4:1 ratio**
    - **left, right, top, bottom**
    - **record mean of each**



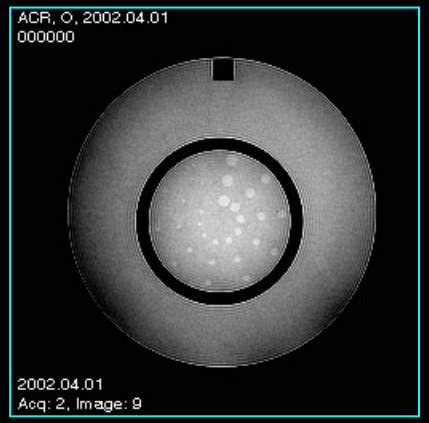
$$\text{ghosting ratio} = \left| \frac{(top + bottom) - (left + right)}{(2 \times (\text{large ROI})} \right|$$

  - **performance criteria:**
    - **ghosting ratio ≤ 0.025 (2.5%)**

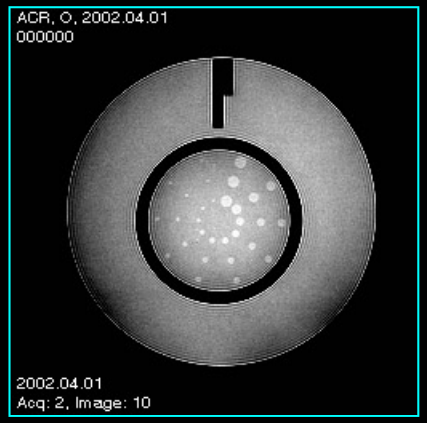
low-contrast object detectability

- slices 8-11
- both ACR series
- both site series
- adjust window/level for optimum contrast.

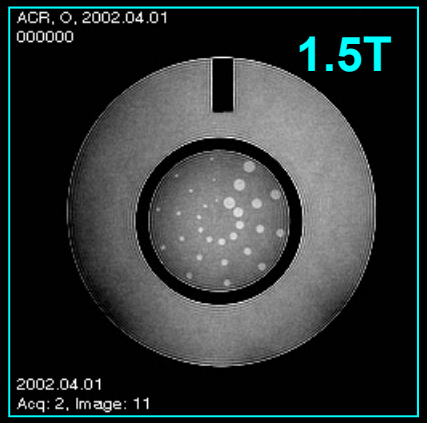
slice 8



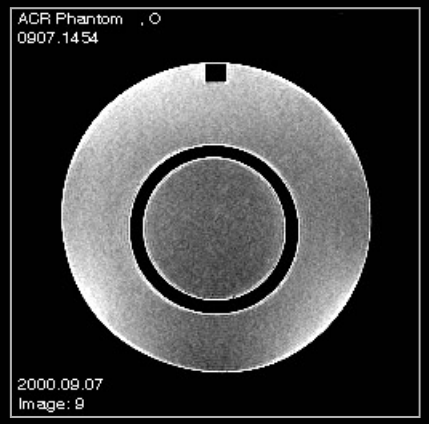
slice 9

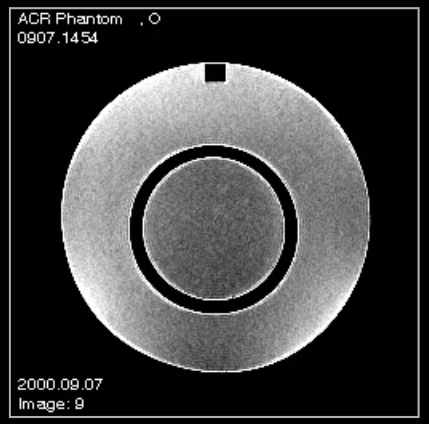


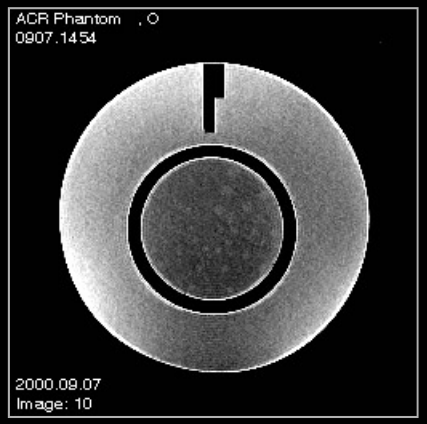
slice 10

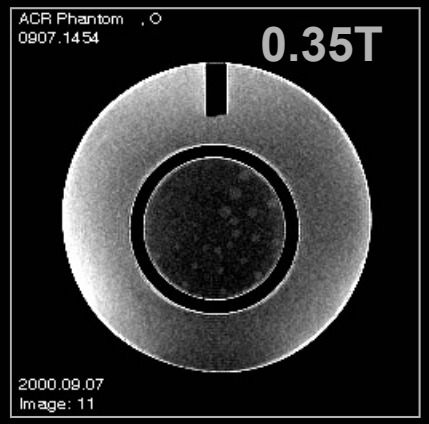


slice 11



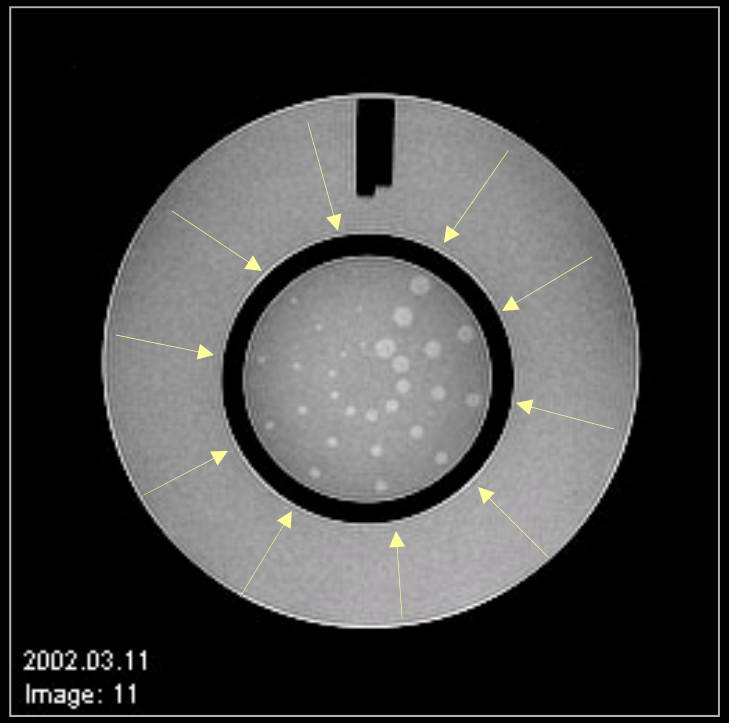






low-contrast object detectability

- **4 slices with low-contrast holes**
  - **slices 8-11**
    - **decreasing contrast levels (11→ 8)**
  - **10 spokes per slice**
    - **3 holes per spoke**
    - **decreasing size (clockwise)**
- **count complete spokes**
  - **all 3 disks must be discernible**
    - **more apparent than background**
  - **end with last complete spoke**
  - **for phantom review:**
    - **all slices are counted**
    - **total score = discernible spokes from all four slices**



low-contrast object detectability – small phantom

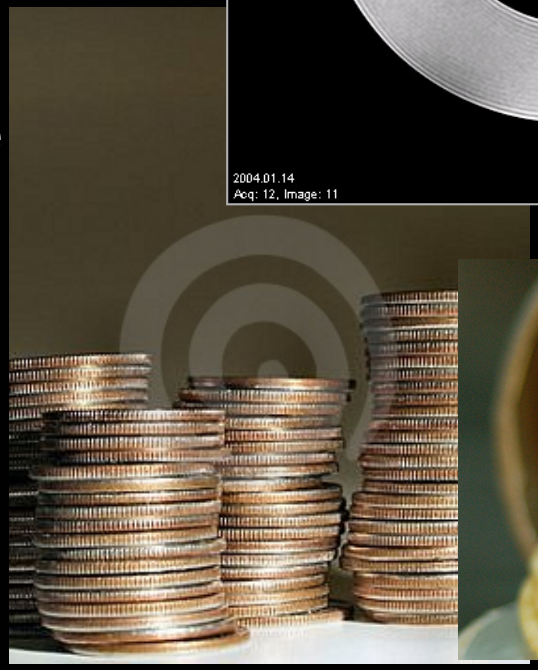
- **2 slices with low-contrast holes**
  - **slices 6-7**
    - **decreasing contrast levels (7→ 6)**
  - **10 spokes per slice**
    - **3 holes per spoke**
    - **decreasing size (clockwise)**

low-contrast object detectability

- **performance criteria**
  - **each ACR series should have a total score of at least 9 spokes**
    - **4 slices for large phantom (9/40)**
    - **2 slices for small phantom (9/20)**
  - **for 3.0T, the total score must be at least 37 spokes.**
  - **must pass both ACR series or both site series**

low-contrast object detectability

- **causes of failure:**
  - incorrectly positioned slices
    - contrast based on partial volume averaging
  - tilted phantom
  - warped slices / B_0 inhomogeneity correction software
  - incorrect slice thickness
  - ghosting
  - inadequate SNR



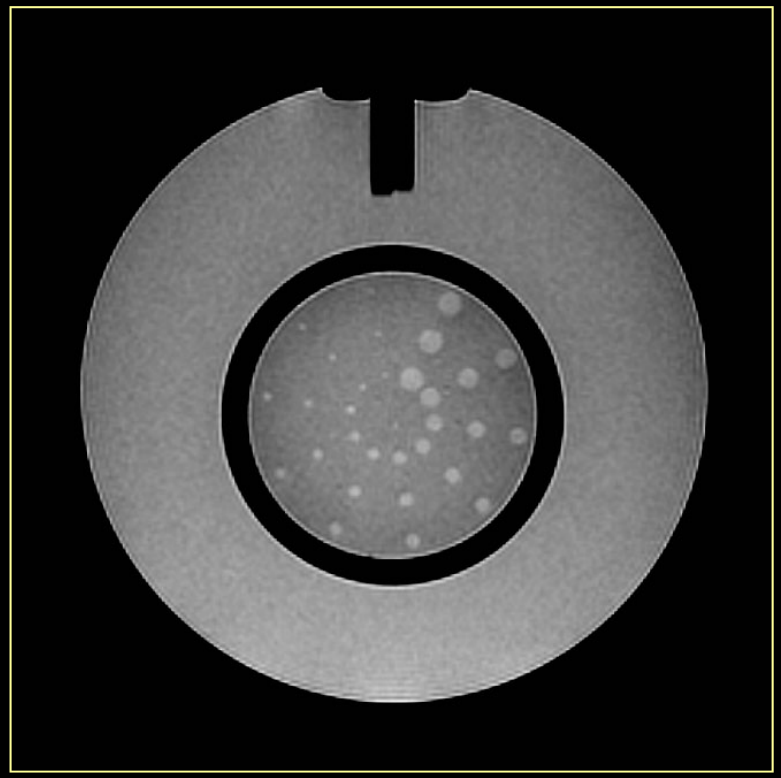
low-contrast object detectability

- **notes:**
  - **several lower spokes may be visible but cannot be counted due to artifact obscuring one of the higher-level spokes**
  - **window/level each slice separately**
  - **start with highest contrast and move down.**
  - **site may need to change their protocol**
    - **(especially for low field magnets)**

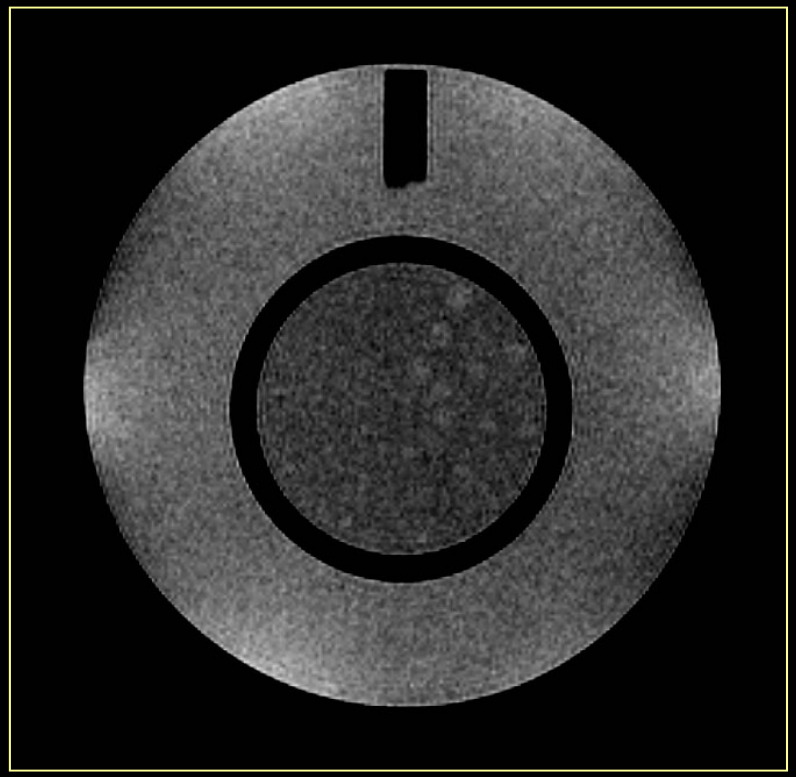
low-contrast: high vs. low field

- slice 11 - ACR T1 series

1.5 T



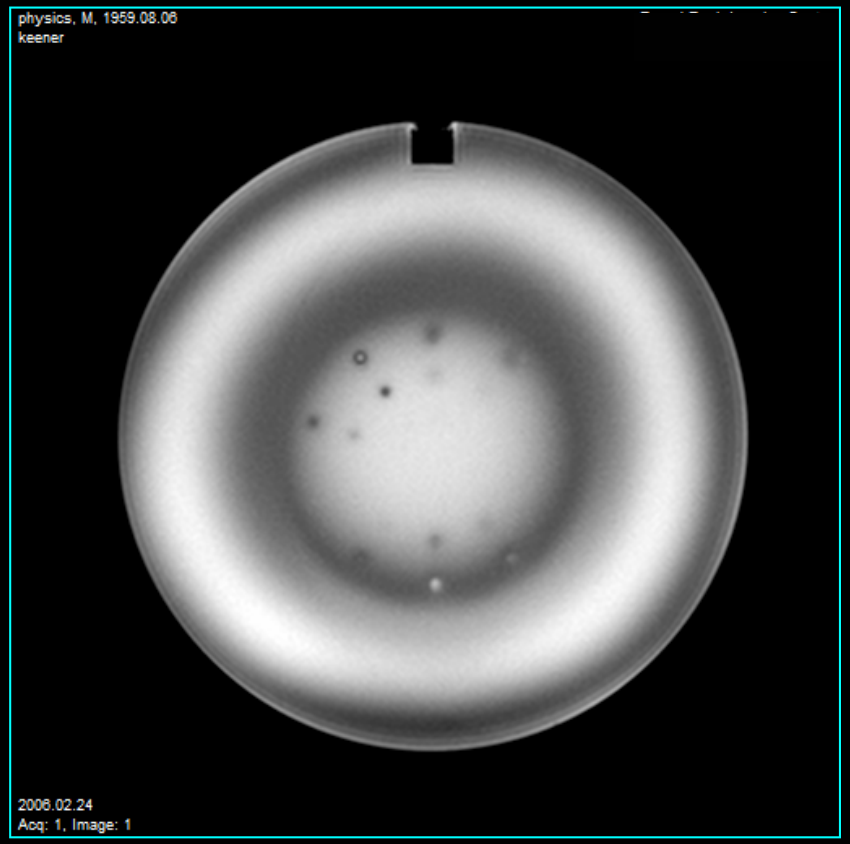
0.3 T



artifacts

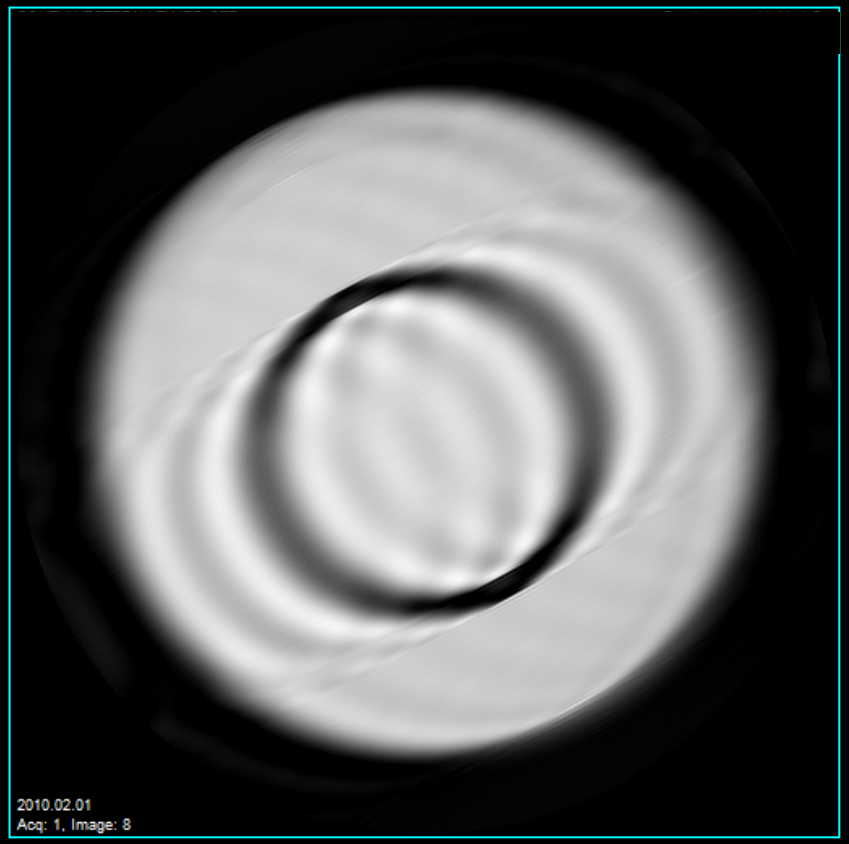
ACR series

artifacts are evaluated



site series

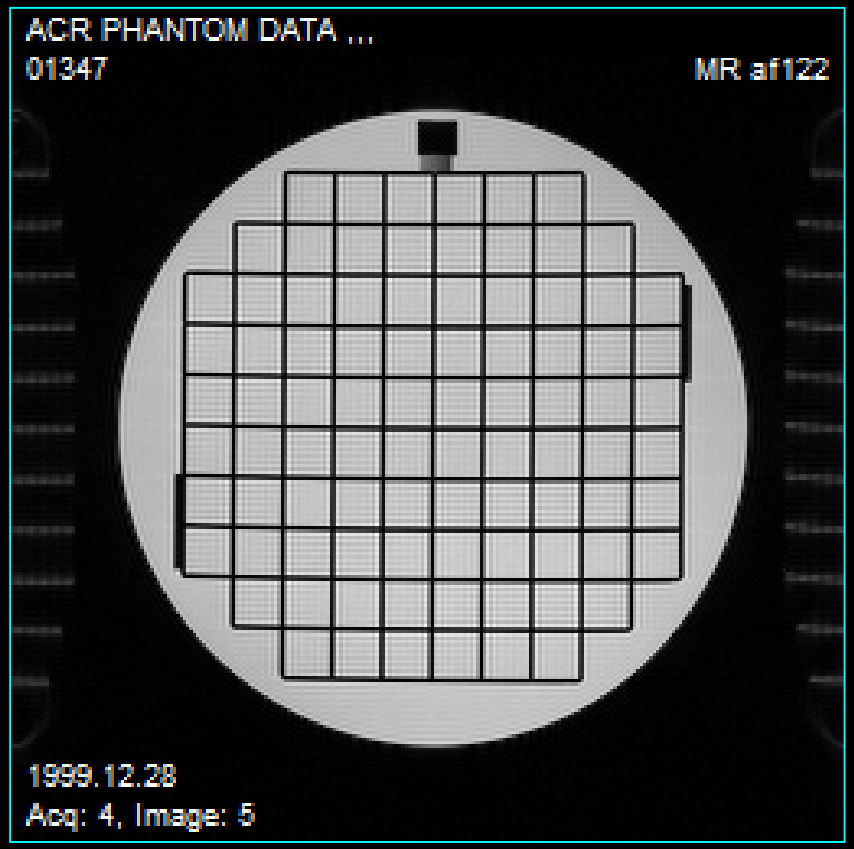
artifacts are NOT evaluated



artifacts

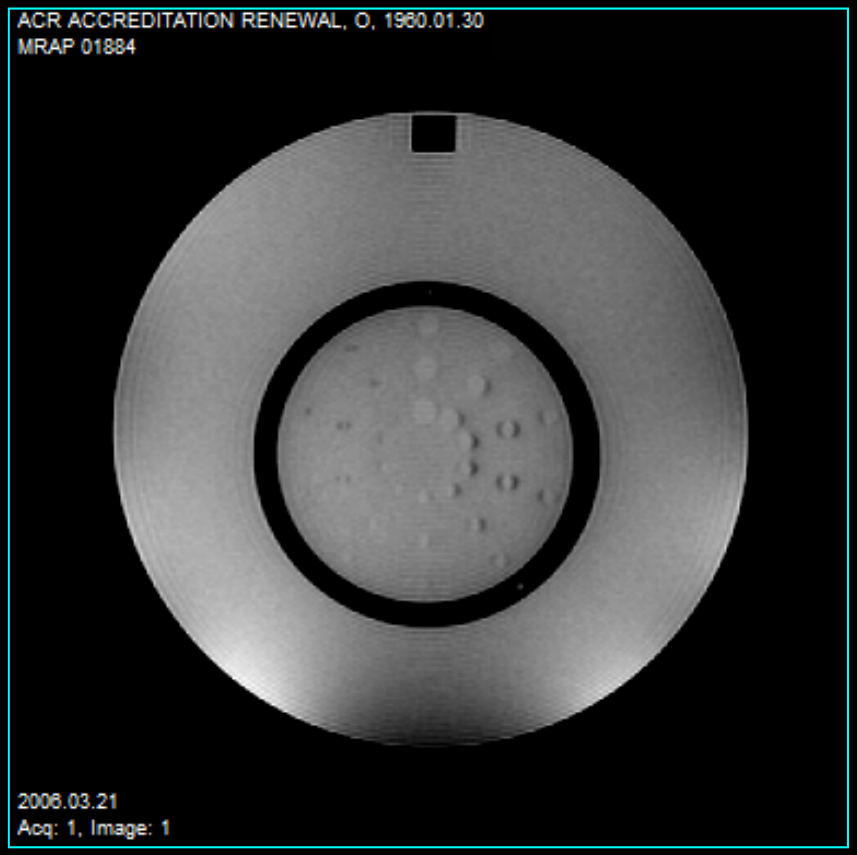
DC Offset (ACR series)

acceptable



susceptibility (ACR series)

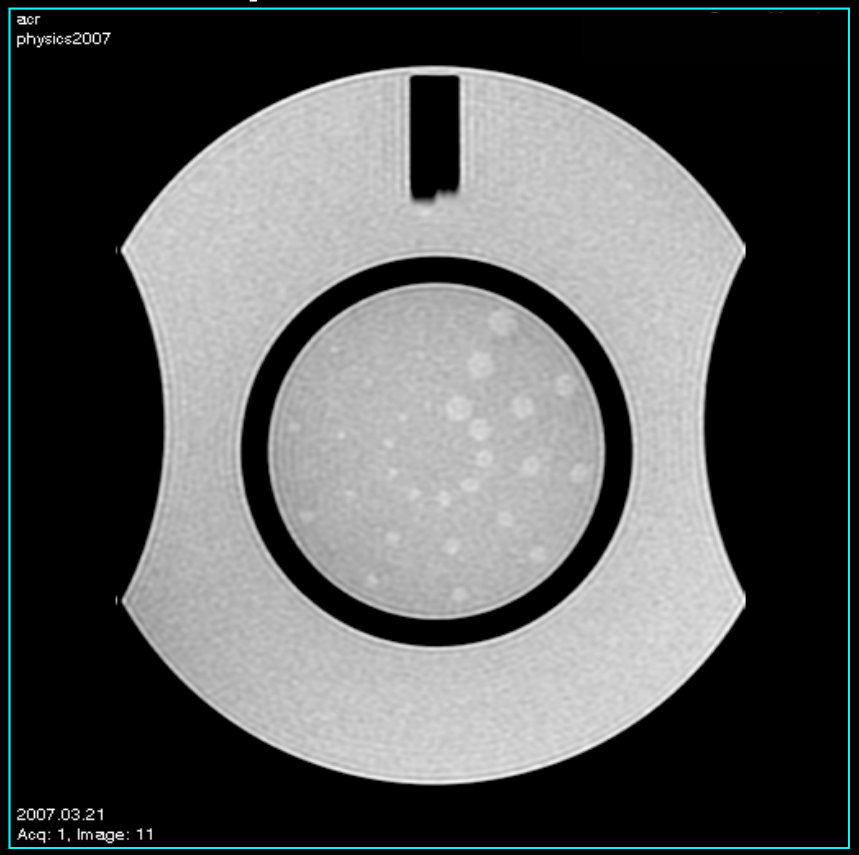
questionable



artifacts

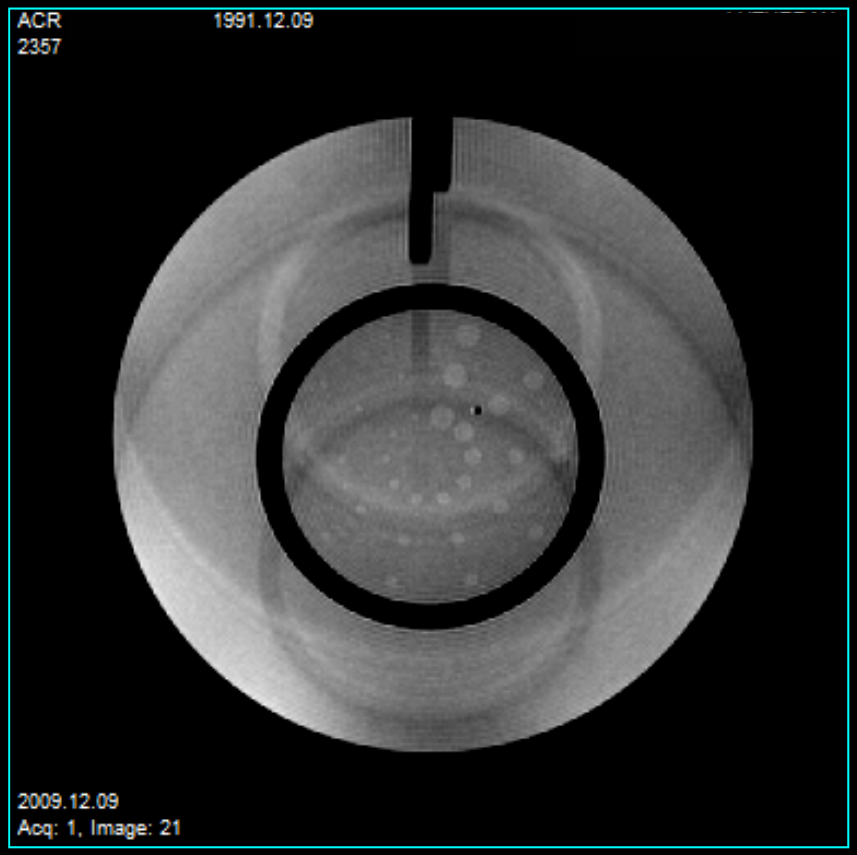
wraparound (site series)

acceptable



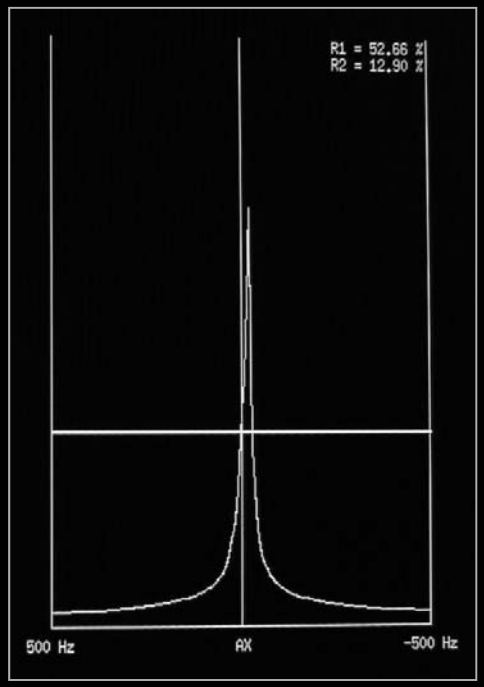
ghosting (ACR T2)

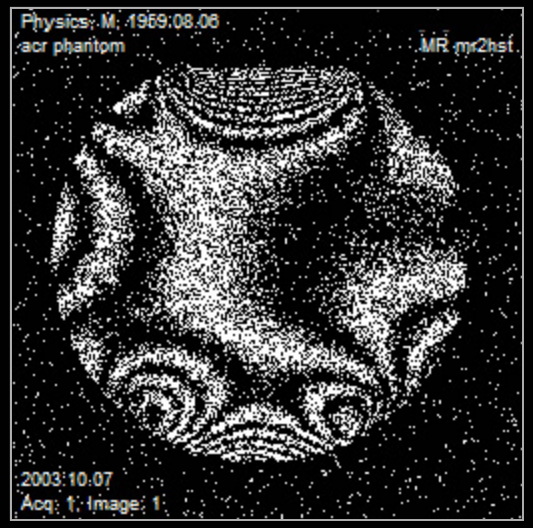
questionable

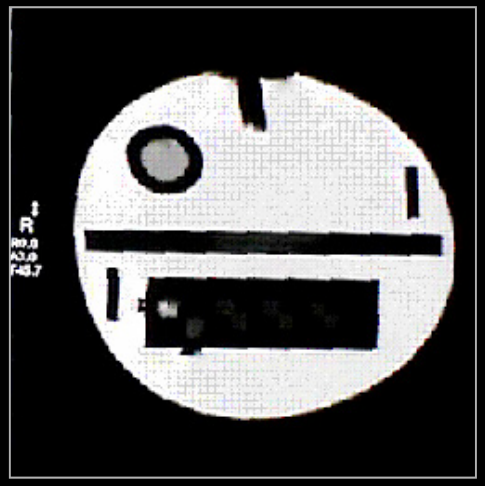


homogeneity

- required for annual survey & initial evaluation
- concerns
  - geometric distortion?
  - problems with fat saturation?
- methods
  - spectral
  - phase-difference
  - visual distortion

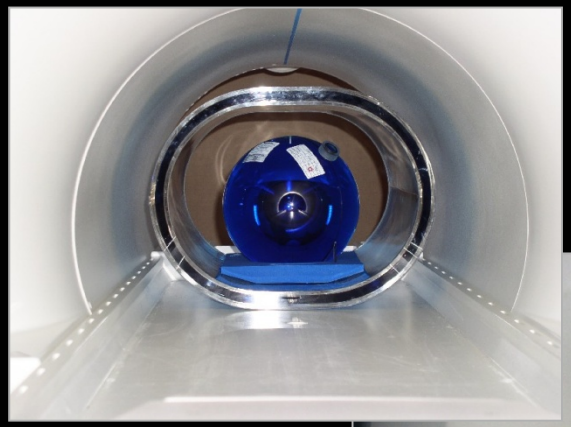


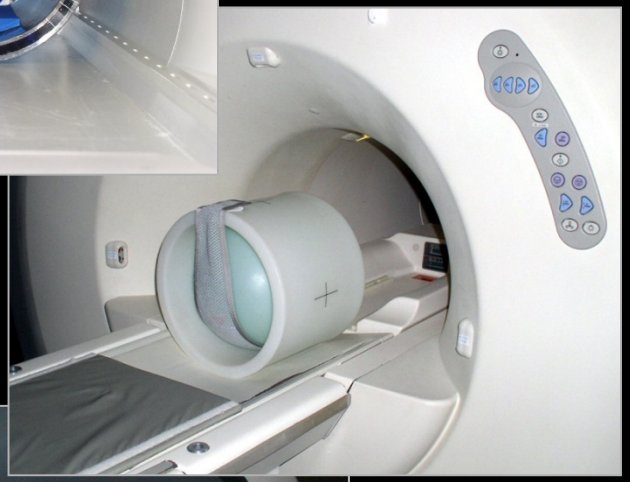




homogeneity – spectral analysis

- **measures frequency of signal-producing phantom in magnet**
  - **DSV**
    - **↑ homogeneity at center & with ↓ FOV**
    - **Δ FOV… Δ phantom size**
  - **spectrum displayed on screen (Hz)**
  - **homogeneity measured in ppm**
  - **compare to specs or baseline values**



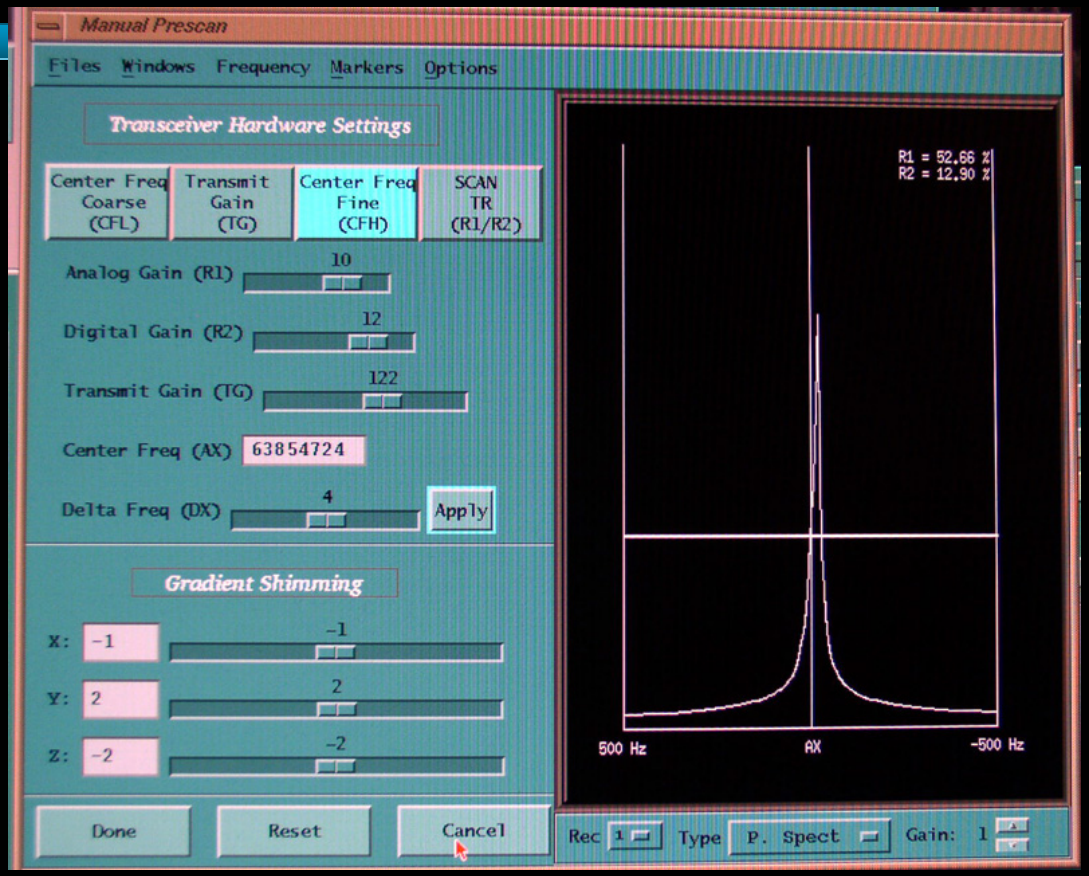


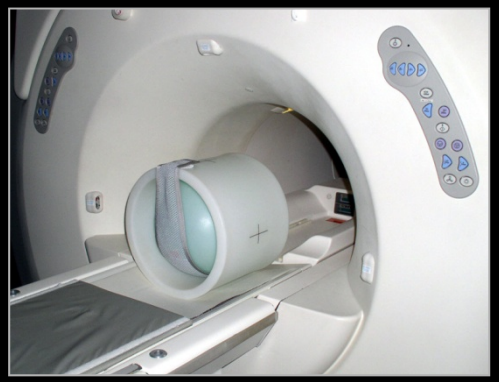
homogeneity – spectral analysis

- **manual prescan**
  - **GE**
- **EPI tuning**
  - **Elscint**
- **FWHM (Hz)**

$$ppm = \frac{Hz_{FWHM}}{MHz_{LarmorFrequency}}$$

  - **volume ~ phantom**

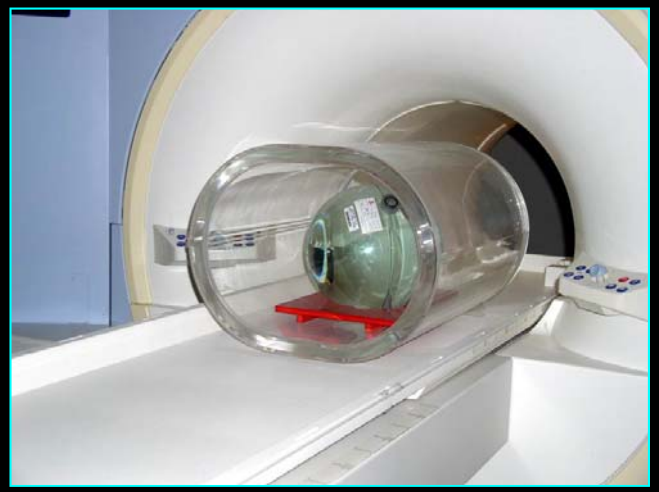


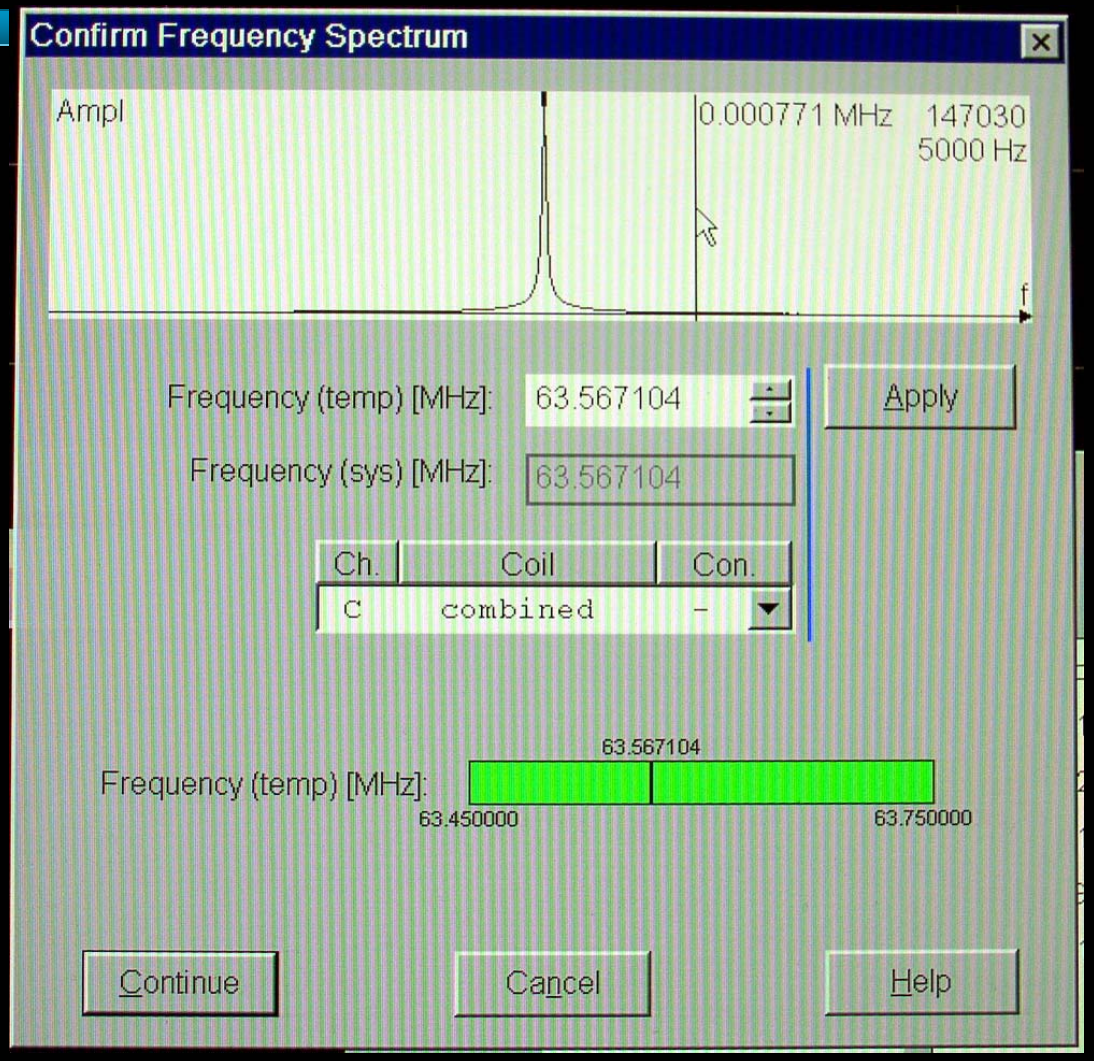


Orientation	DSV (cm)	PPM
DSV	27	0.38

homogeneity – spectral analysis

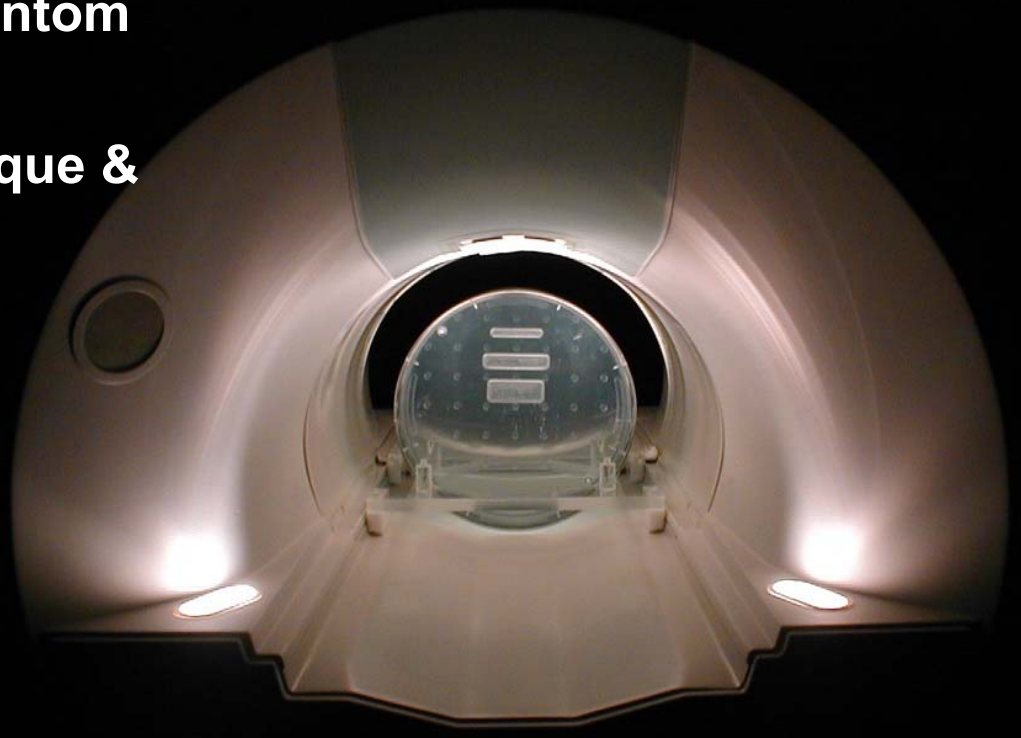
- **Siemens**
  - **“system” “adjustments”**
  - **check “confirm adjustments”**





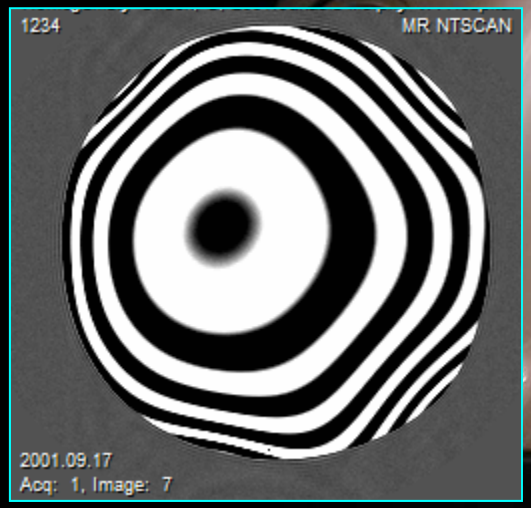
phase-difference (Philips)

- **shim_check**
  - option under phantom studies
  - FFE, fixed technique & FOV
- **40 cm cylindrical phantom**
  - holder to center phantom
  - 3 orientations
- **view real images**
  - count B→W transitions



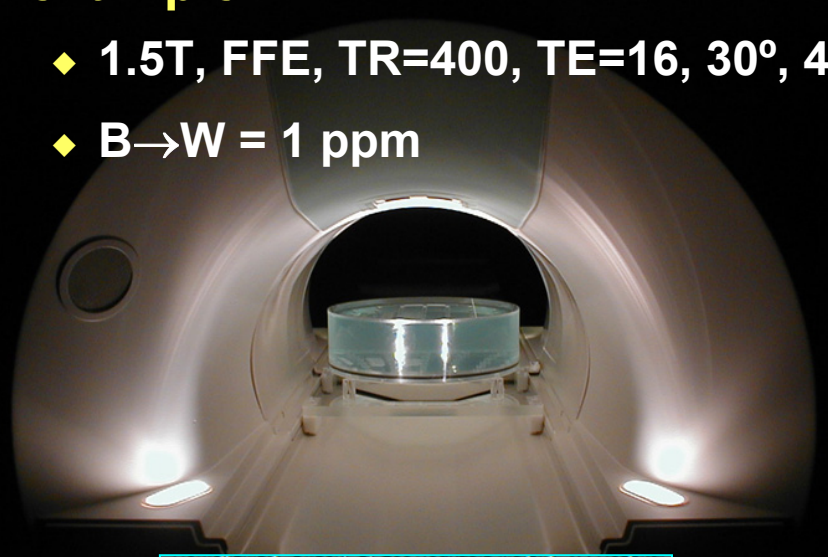
shim_check (Philips)

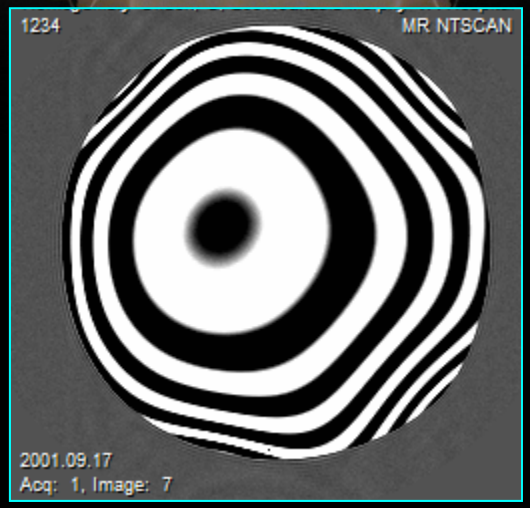
- **example:**
  - **1.5T, FFE, TR=400, TE=16, 30º, 450 mm FOV**
  - **B→W = 1 ppm**
- **example:**
  - **coin taped to phantom**



shim_check (Philips)

- **example:**
  - **1.5T, FFE, TR=400, TE=16, 30º, 450 mm FOV**
  - **B→W = 1 ppm**

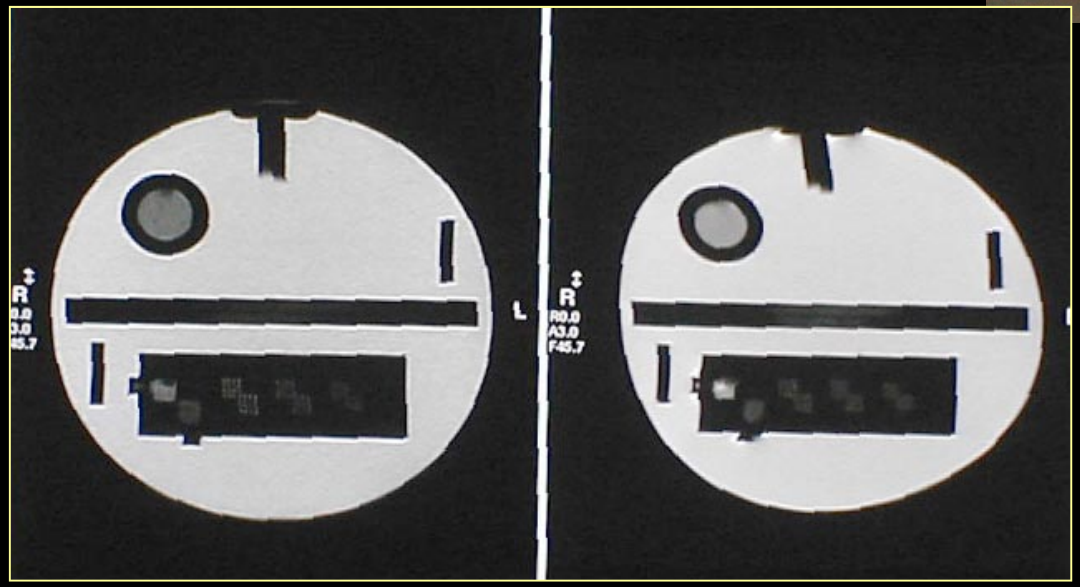




Orientation	DSV (cm)	PPM
transverse	40	10
sagittal	40	10
coronal	40	8
transverse	20	1.5
sagittal	20	2
coronal	20	2

homogeneity – geometric distortion

- **most low-field open magnets do not have software to check homogeneity**
  - **observe effects on geometric distortion**
    - **lower bandwidth**
  - **warped images**



7.4 kHz **3.6 kHz**

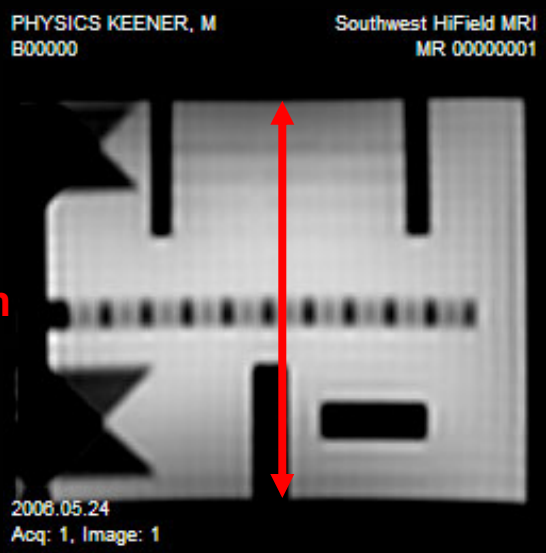
different bandwidths

- **measure distortion in frequency-encoding direction with different bandwidths** ***(Clarke & Chen)***

$$MFH(ppm) = \frac{(BW_1 \times BW_2) \times (x_1 - x_2)}{(\gamma/2\pi) B_0 FOV (BW_2 - BW_1)}$$

BW=33 Hz (8448 kHz)

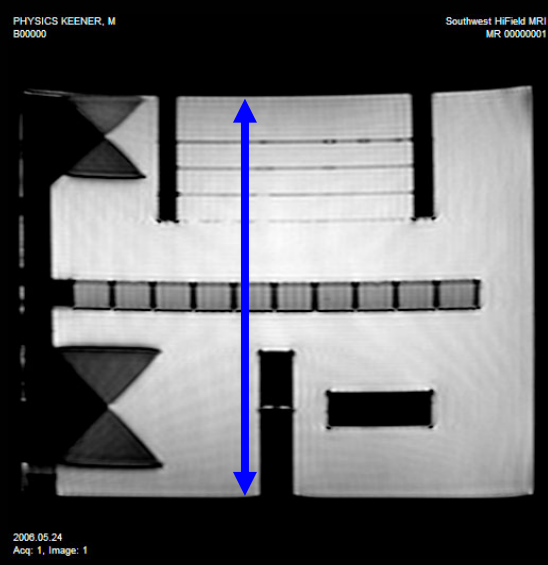
FE45 TR=256, TE=45, 7 mm, FA=70°, FOV=20cm



148.1 cm

BW=244 Hz (62464 kHz)

FE5.0 TR=256, TE=5, 7 mm, FA=20°, FOV=20cm

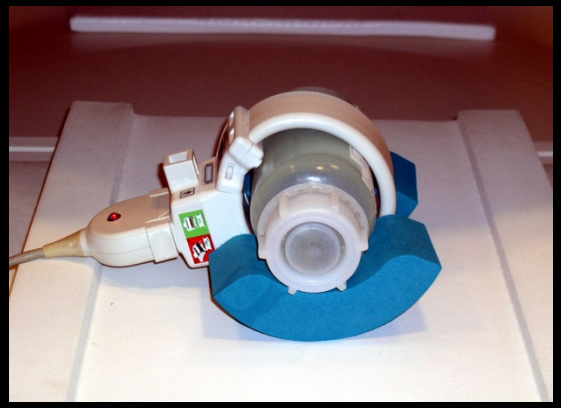


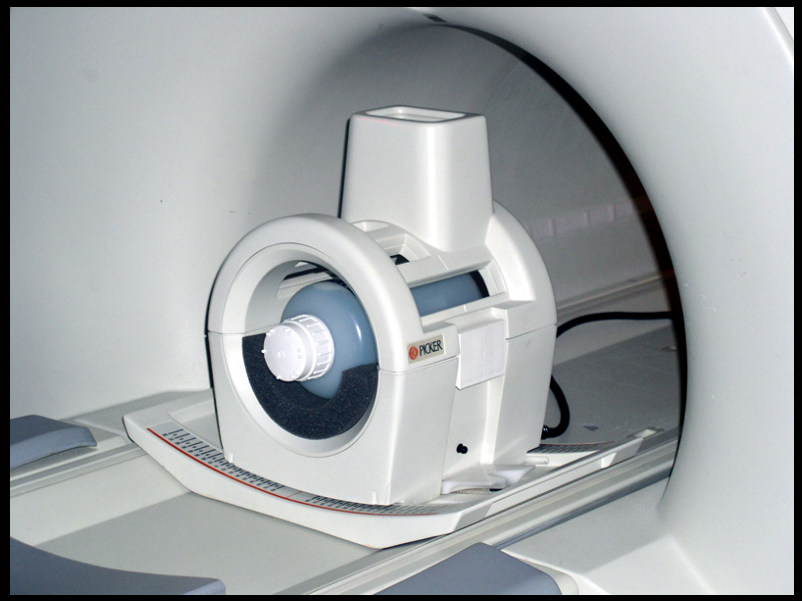
151.6 cm

SI	2.68 ppm
AP	0.84 ppm
LR	0.31 ppm

coils

- must be checked annually
  - SNR
  - ghosting
  - uniformity



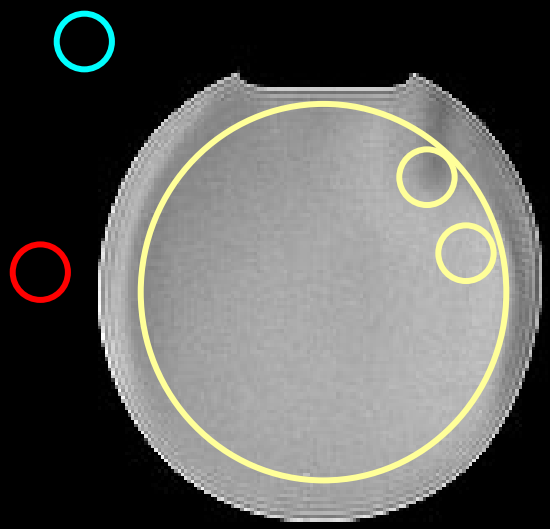


volume coils

MARP, Inc.

000000 MR NTSCAN

- similar to head coil
  - uniformity
    - mean
    - high
    - low
  - SNR
    - mean
    - background noise
  - ghosting
    - mean
    - background signal
    - ghost signal (PE direction)
  - phased-array coils
    - may be treated as volume if they have volume configuration

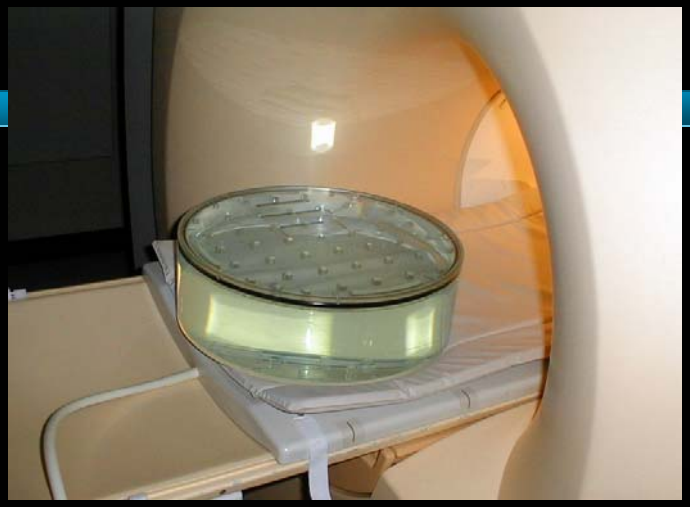


Orientation	axial		
Mean ROI	1807.97	Mean Background	18.10
Min ROI	1690.80	Background StdDev	10.01
Max ROI	1942.68	Ghost Signal	20.15

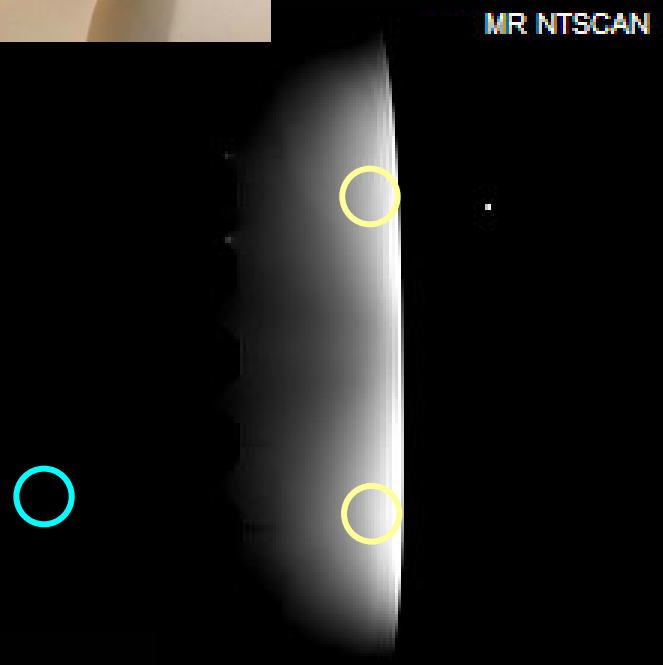
Head Coil Only
Copy ACR T1 uniformity data

Survey Date	RF Drive Scale	Mean SNR	Uniformity	Ghosting Ratio
May 31, 2007	0.90	180.6	93.07%	0.06%
May 18, 2006	0.97	316.5	97.17%	0.18%
May 24, 2005	0.89	369.3	97.33%	0.11%
May 11, 2004	0.94	356.1	97.72%	0.39%

surface coils



- max SNR
  - max ROI
  - background noise
- uniformity
  - subjective
- ghosting
  - subjective
- phased-array coils
  - may be treated multiple surface coils if you can distinguish the location of the arrays



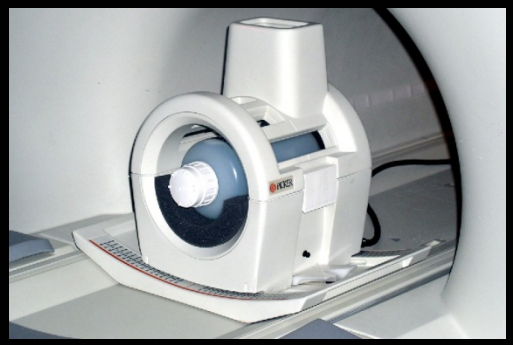
Orientation axial

Max ROI 1828.85 Background StdDev 3.47

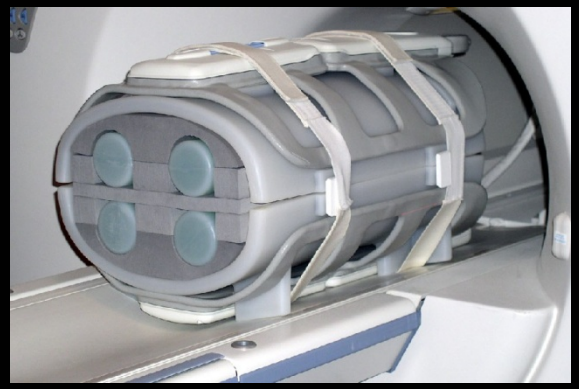
Survey Date	Max SNR	RF Drive Scale	Uniformity OK?	Ghosting OK?
May 31, 2007	527.0	1.04	good	none
May 18, 2006	518.6	1.09	good	none
May 24, 2005	509.8	1.01	good	slight
May 11, 2004	467.2	1.06	ok	none

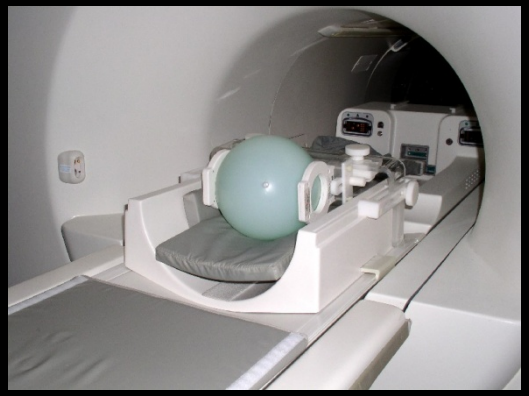
phased-array coils

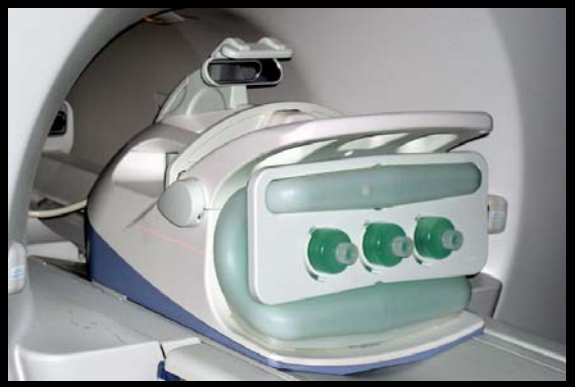
- **multiple types**



~ volume coil







~ multiple surface coils
(arrays distinguishable)

more complicated

recommendations

- be familiar with process
  - read QC manual, phantom guidance & site instructions
  - set up worksheet or computer program
  - let site know if they will pass phantom portion
- scan early in the process
  - site may need to adjust protocols prior to acquisition of clinical and phantom images
  - before application to let site know condition of magnet prior to due date
  - magnet may be “in specs” and still fail part of the test
  - magnet may need corrections prior to phantom submission

recommendations

- physician
  - two-month window to get clinical images
  - may need to adjust protocols
- service engineer
  - magnet should be in top shape prior to obtaining images
- technologist
  - needs assistance in setting up QC
  - schedule ~ 5 hours

conclusion

- **physicist**
  - **there is no reason a site should fail the phantom portion of the MRI Accreditation program if they are being assisted by a physicist**
  - **phantom materials submitted by physicist should be usable by ACR**
  - **physicist should be able to perform all tests required by ACR**

application & submission resources

- **www.acr.org**
  - **application & submission documents**
    - **all changed ~ November 2008**
  - **phantom submission & site scanning documents**
    - **unchanged for large phantom**
    - **added small phantom ~ November 2008**

Physicist's Role in ACR MRAP Accreditation

May 2010

Carl R. Keener, Ph.D., DABMP, DABR
keener@MARPinc.com

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