

# MRI SCANNER PERFORMANCE EVALUATION

## GREEN LIGHT IMAGING, LLC

Medical Mobile Diagnostics  
8348 Rosemead Blvd  
Pico Rivera, CA 90660

### MRI Trailer

GE Genesis Signa Horizon LX 1.5T  
S/N: R2947  
Software Verison: 12.0

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## TEST RESULTS SUMMARY

| MRI Performance Evaluation Test               | PASS/FAIL/NA |
|-----------------------------------------------|--------------|
| 1. Table Positioning & Setup Evaluation       | PASS         |
| 2. Acquisition Console Check                  | PASS         |
| 3. Center Frequency Check                     | PASS         |
| 4. Transmitter Gain Consistency               | PASS         |
| 5. Geometric Accuracy                         | PASS         |
| 6. High Contrast Spatial Resolution           | PASS         |
| 7. Slice Thickness Accuracy                   | PASS         |
| 8. Slice Position Accuracy                    | PASS         |
| 9. Image Intensity Uniformity                 | PASS         |
| 10. Percent Signal Ghosting                   | PASS         |
| 11. Low Contrast Object Resolution Evaluation | PASS         |
| 12. Magnetic Field Homogeneity Evaluation     | PASS         |
| 13. RF Coil Performance Evaluation            | PASS         |
| 14. Soft Copy Display Evaluation              | PASS         |
| 15. Site Technologist QC Program evaluation   | PASS         |
| 16. Assessment of MRI Safety Program          | PASS         |

## PULSE SEQUENCE ACQUISITION PARAMETERS

### ACR Sagittal Localizer:

Spin Echo, TR 200, TE 20, 1 NEX, FA 90, Slice Thickness 20 mm, 25 cm FOV  
256x256 matrix,  $\pm$  15.63 kHz BW, 0:56 Scan Time, Scan Options: None

### ACR Axial T1-weighted Scan:

Spin Echo, TR 500, TE 20, 1 NEX, FA 90, Slice Thickness 5 mm Skip 5 mm, 25 cm FOV  
256x256 matrix,  $\pm$  15.63 kHz BW, 2:16 Scan Time, Scan Options: None

### ACR Axial T2-weighted Scan:

Spin Echo, TR 2000, TE 20/80, 1 NEX, FA 90, Slice Thickness 5 mm Skip 5 mm, 25 cm FOV  
256x256 matrix,  $\pm$  15.63/10.0 kHz BW, 8:56 Scan Time, Scan Options: None

### Site T1-weighted Scan:

FSE-XL, TR 650, TE 13.4, ET 5, 2 NEX, FA 90, Slice Thickness 5 mm Skip 5 mm, 20x22 cm FOV,  
192x320 matrix,  $\pm$  31.2 kHz BW, 1:39 Scan Time, Scan Options: FC, St: I, TRF, Z512

### Site T2-weighted Scan:

FSE-XL, TR 3400, TE 102, ET 23, 2 NEX, Slice Thickness 5 mm Skip 5 mm, 20x22 cm FOV,  
224x320 matrix,  $\pm$  31.25 kHz BW, 1:15 Scan Time, Scan Options: FC, EDR, TRF, FAST, Z512

## RECOMMENDATIONS AND COMMENTS

- \* Above listed tests were performed in accordance with ACR MRI accreditation program guidelines, using the ACR MRI phantom and assorted manufacturer provided phantoms.
- \* Table positioning and acquisition console operation performance was found to be adequate.
- \* Slice positioning accuracy was found to be adequate, within 2 mm of the prescribed value. Slice thickness accuracy and contiguity were found to be within acceptable limits also.
- \* No significant image non-uniformities or distortions were noted in any of the axial, sagittal and coronal planes.
- \* Signal to noise measurements were found to be adequate, consistent with pulse sequence parameters.
- \* RF volume and surface coil performance evaluations were found to be adequate, with no significant image non-uniformities and ghosting artifacts.
- \* Technologists QC program is well established. Daily SNR measurements are being performed and properly documented.

For further details about this performance evaluation please contact KJ Jerjian, Ph.D., at (949)683-5215, or by e-mail at [kjmedicalphysics@gmail.com](mailto:kjmedicalphysics@gmail.com).

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Date: 02/19/2021

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Medical Physicist

## 1. TABLE POSITION & SETUP CHECK

This check is performed to determine that the MRI scanner is functioning properly during patient setup, data entry and pre-scan tasks.

### Results:

- a. Table docking, raising, lowering and positioning was verified to be functional and working properly.
- b. Warning lights, indicator lights and emergency buttons all were functional and working properly.
- c. Center of the sagittal image of the phantom was within the recommended  $\pm 2$  mm of the central grid structure of the phantom.

## 2. ACQUISITION CONSOLE CHECK

This check is performed to determine that the MRI scanner acquisition console and workstation is functioning properly during patient setup, data entry and pre-scan tasks.

### Results:

- a. System shut down and startup functions execute properly.
- b. The scanner interface, including mouse, keyboard and display were all functioning properly.
- c. RIS and PACS system interface features were functional and system performance was found to be adequate.

### 3. CENTER FREQUENCY CHECK

This check is performed to determine that the MRI scanner is set on resonance for optimum system sensitivity and signal-to-noise ratio (SNR).

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** Automatic coil tuning & transmitter gain parameter adjustments

The ACR phantom was leveled and positioned in the head coil at the center of the magnet and automatic system adjustment (coil tuning) was performed for optimum system sensitivity and SNR. Coil tuning and transmitter attenuation and/or gain parameters were recorded for comparison purposes.

**Results:**

System determined RF center frequency was 63.860686 MHz, well within 2 ppm compared to results from last year..

**Conclusion:**

Coil tuning and transmitter gain parameters were found to be adequate, well within acceptable operating ranges. In general, weekly variation in center frequency is estimated not to exceeded  $\pm 2.5$  ppm (~ 150 Hz).

### 4. TRANSMITTER GAIN EVALUATION

This evaluation of fluctuations in the transmitter attenuation (or gain) in automatic pre-scan system adjustment and tuning mode is performed to assess problems in the radio frequency (RF) chain.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** Automatic coil tuning & transmitter gain parameter adjustments

The ACR phantom was leveled and positioned in the head coil at the center of the magnet and automatic system adjustment (coil tuning) was performed for optimum system sensitivity and SNR. Coil tuning and transmitter attenuation and/or gain parameters were recorded for comparison purposes.

**Results:**

The Transmitter Attenuation was determined to be 104 dB (ACR T1 Axial Mode).

**Conclusion:**

Coil tuning and transmitter gain parameters were found to be adequate, well within acceptable operating ranges.

## 5. GEOMETRIC ACCURACY

This test assesses the accuracy with which the MR image represents dimensional lengths of an object. A failure of this test means that there are significant distortions in the image and that measurements differ substantially more than it is expected from a properly functioning MR scanner.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Weighted Sequences

Geometric accuracy was tested in both axial and sagittal planes to assess performance in all three orthogonal gradient directions. Horizontal and vertical distance measurements were made using the system distance measuring tool. The sagittal localizer and axial slices #1 and #5 were used.

### Results:

System measured dimensions of the phantom were compared to the actual phantom dimensions. The inside length and inside diameter of the phantom are 148 mm and 190 mm, respectively. Action limit is  $\pm 2$  mm.

|                           | Horizontal Dimension | Vertical Dimension | Diagonal (+ 45°) | Diagonal (- 45°) | Maximum Deviation |
|---------------------------|----------------------|--------------------|------------------|------------------|-------------------|
| <b>Sagittal Localizer</b> |                      |                    |                  |                  |                   |
| Sag. Image #1             | ---                  | 147 mm             | ---              | ---              | - 1 mm            |
| <b>T1w Scan</b>           |                      |                    |                  |                  |                   |
| Axial Image #1            | 189 mm               | 190 mm             | ---              | ---              | - 1 mm            |
| Axial Image #5            | 189 mm               | 189 mm             | 188 mm           | 189 mm           | - 1 mm            |
| <b>T2w Scan</b>           |                      |                    |                  |                  |                   |
| Axial Image #1            | 189 mm               | 189 mm             | ---              | ---              | - 1 mm            |
| Axial Image #5            | 188 mm               | 190 mm             | 189 mm           | 189 mm           | - 1 mm            |

### Conclusion:

Phantom dimension measurements were within the ACR recommended  $\pm 2$  mm limits. There are no significant geometric distortions in both axial and sagittal planes.

## 6. HIGH CONTRAST SPATIAL RESOLUTION

The high contrast spatial resolution test assesses the scanner's ability to resolve small objects when the contrast-to-noise ratio is sufficiently high that it does not play a role in limiting system spatial resolution ability.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Sequences and Site T1 and T2 Sequences

Images of the resolution insert in slice #1 containing three different arrays of holes with hole diameters measuring 1.1 mm, 1.0 mm and 0.9 mm were obtained using a 5 mm slice thickness. The smallest size holes resolved under optimal viewing conditions in both the frequency and phase encoding directions was determined.

### Results:

|                           | Frequency Encoding Direction | Phase Encoding Direction |
|---------------------------|------------------------------|--------------------------|
| ACR T1 Weighted Sequence  | 1.0 mm                       | 1.0 mm                   |
| ACR T2 Weighted Sequence  | 1.0 mm                       | 1.0 mm                   |
| Site T1 Weighted Sequence | 0.9 mm                       | 1.1 mm                   |
| Site T2 Weighted Sequence | 0.9 mm                       | 1.0 mm                   |

### Conclusion:

The field of view and matrix size for the axial ACR series are chosen to yield a resolution of close to 1.0 mm in both directions. The smallest size holes resolved in both the frequency and phase encoding directions were determined to be consistent with pulse sequence parameters. Factors contributing to high-contrast resolution include field-of-view (determined by gradient strength and sampling period), acquisition matrix and reconstruction filters.

## 7. SLICE THICKNESS ACCURACY

The slice thickness accuracy test assesses the accuracy with which a slice of a specified thickness is actually achieved.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Sequences and Site T1 and T2 Sequences

T1 and T2 weighted images of the "slice thickness insert" in slice #1 were obtained using 5 mm slice thicknesses. Following the adjustment of the window/level setting to about one full-width-half-max (FWHM) of the signal producing ramps, the top and bottom signal ramps were measured. The slice thickness was computed using the following equation, where the factor 0.1 is used to account for the slope of the ramps.

$$\text{Slice Thickness} = 0.1 * (2 * \text{Top Ramp} * \text{Bottom Ramp}) / (\text{Top Ramp} + \text{Bottom Ramp})$$

### Results:

The slice thickness evaluation insert was measured with a narrow window width and a window level setting of about one FWHM.

|                           | Top Ramp | Bottom Ramp | Slice Thickness |
|---------------------------|----------|-------------|-----------------|
| ACR T1 Weighted Sequence  | 48 mm    | 57 mm       | 5.2 mm          |
| ACR T2 Weighted Sequence  | 50 mm    | 54 mm       | 5.2 mm          |
| Site T1 Weighted Sequence | 51 mm    | 58 mm       | 5.4 mm          |
| Site T2 Weighted Sequence | 52 mm    | 57 mm       | 5.4 mm          |

### Conclusion:

Slice thickness accuracy was found to be adequate. For a nominal slice thickness of 5 mm, the measured value should be in the range of  $5.0 \pm 0.7$  mm. Factors that could adversely affect the slice thickness accuracy include the gradient field and rf field uniformity, non-uniform static field, non-coplanar slice selection pulses between excitation and readout, TR/T1 ratio, and rf pulse shape and stimulated echoes.



## 8. SLICE POSITION ACCURACY

The slice position accuracy test assesses the accuracy with which slices can be prescribed at specific locations utilizing the graphical localizer image for positional reference.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 Weighted Sequence

Multi-slice T1 weighted images were obtained using the ACR T1 weighted protocol with a slice thickness of 5 mm and a gap of 5 mm. In axial slices #1 and #11, the crossed wedges appear as a pair of adjacent, dark, vertical bars at the top of the phantom. The bar length differences at prescribed locations were measured. Note that a bar length difference of zero indicates a slice position accuracy that is perfectly aligned with the vertex of the crossed wedges, and that by design of the wedges, the bar length difference is twice the actual slice displacement error.

### Results:

Slice position accuracy was evaluated using the paired crossed wedges of the ACR MRI phantom.

|                                 | ACR T1 Axial<br>Image #1 | ACR T1 Axial<br>Image #11 |
|---------------------------------|--------------------------|---------------------------|
| Expected Bar Length Difference  | 0.0 mm                   | 0.0 mm                    |
| Measured Bar Length Difference  | 3.0 mm                   | 1.0 mm                    |
| Actual Slice Displacement Error | 1.5 mm                   | 0.5 mm                    |

|                                 | ACR T2 Axial<br>Image #1 | ACR T2 Axial<br>Image #11 |
|---------------------------------|--------------------------|---------------------------|
| Expected Bar Length Difference  | 0.0 mm                   | 0.0 mm                    |
| Measured Bar Length Difference  | 3.0 mm                   | 1.0 mm                    |
| Actual Slice Displacement Error | 1.5 mm                   | 0.5 mm                    |

Results indicate a slice position accuracy of better than 2 mm and inter-slice gap accuracy of better than 1.0 mm over a range of 10 cm, corresponding to 11 slices and 10 inter-slice gaps.

### Conclusion:

Slice position accuracy was found to be adequate. The magnitude of each bar length difference should be less than or equal to 5 mm corresponding to a slice positioning accuracy of 2.5 mm or better. Factors that could adversely affect the slice thickness accuracy include the gradient field and rf field uniformity, non-uniform static field, non-coplanar slice selection pulses between excitation and readout, TR/T1 ratio, and rf pulse shape and stimulated echoes.

## 9. IMAGE INTENSITY UNIFORMITY

The image uniformity test measures the uniformity of the image signal near the middle of the coil.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Sequences and Site T1 and T2 Sequences

Non-interleaved, multi-slice images of the flood section of the ACR MRI phantom were obtained using a 5 mm slice thicknesses with a skip of 5 mm. A region approximately equal to 75% of the image is evaluated to determine maximum (S<sub>max</sub>) and minimum (S<sub>min</sub>) signal values. The percent integral uniformity (PIU) is evaluated using the following formula:

$$U = 100 * [ 1 - (S_{max} - S_{min}) / (S_{max} + S_{min}) ]$$

### Results:

Note: Using the above formula a value of 100% represents perfect integral uniformity.

|                           | Maximum Signal<br>S <sub>max</sub> | Minimum Signal<br>S <sub>min</sub> | Percent Image<br>Uniformity |
|---------------------------|------------------------------------|------------------------------------|-----------------------------|
| ACR T1 Weighted Sequence  | 1402                               | 1287                               | 96%                         |
| ACR T2 Weighted Sequence  | 865                                | 791                                | 96%                         |
| Site T1 Weighted Sequence | 1570                               | 1405                               | 94%                         |
| Site T2 Weighted Sequence | 818                                | 738                                | 95%                         |

### Conclusion:

System image uniformity was found to be adequate. Percent integral uniformity should be better than 87.5% for systems with field strengths less than 3T, and better than 82% for 3T magnets. Parameters contributing to image non-uniformity include static field in-homogeneity, rf-field non-uniformity, eddy currents, gradient pulse calibration, and image processing. It should be noted that with larger field-of-views, image uniformity may further deteriorate.

## 10. PERCENT SIGNAL GHOSTING

The percent signal ghosting test assesses the level of ghosting artifacts (a faint copy of the imaged object displaced and superimposed on the image).

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Sequences and Site T1 and T2 Sequences

Multi-slice T1 and T2 weighted images of the signal producing region were obtained and the ghosting ratios quantified using ROI measurements in and around the signal producing region in image #7.

Signal ghosting as a fraction of the primary signal is calculated using the following formula:

$$\text{Ghosting Ratio} = \frac{|(\text{Ghost Signal}) - (\text{Background Signal})|}{2 * \text{Large ROI Signal}}$$

Where the ghost signal and background signal are the mean ROI signals in the non-signal producing areas around the phantom in the phase encoding and frequency encoding directions, respectively, and the Large ROI is the mean signal intensity in the middle of signal producing region of the phantom.

### Results:

|                           | Top ROI | Bottom ROI | Left ROI | Right ROI | Large ROI | Ghosting Ratio |
|---------------------------|---------|------------|----------|-----------|-----------|----------------|
| ACR T1 Weighted Sequence  | 12.0    | 11.9       | 11.9     | 12.1      | 1364      | 0.000          |
| ACR T2 Weighted Sequence  | 13.0    | 12.1       | 14.5     | 14.2      | 837       | 0.002          |
| Site T1 Weighted Sequence | 11.6    | 11.0       | 14.0     | 14.0      | 1498      | 0.002          |
| Site T2 Weighted Sequence | 16.5    | 16.0       | 18.9     | 18.6      | 783       | 0.003          |

### Conclusion:

Signal ghosting ratio was found to be adequate. The value for ghosting as a fraction of the primary signal should be less than or equal to 0.025. No obvious smears, ghost images or quadrature errors were apparent in the images. Factors affecting phase related artifacts and ghosting errors include phase encoding gradient instabilities, quadrature maladjustment in synthesis of slice selective rf pulses (transmit errors), and improper quadrature phase decoding on receive.

## 11. LOW CONTRAST OBJECT RESOLUTION

The low contrast object resolution evaluation assesses the extent to which objects of low contrast are discernible in the images.

**Phantom:** ACR MRI Accreditation Phantom

**Test Protocol:** ACR T1 and T2 Sequences and Site T1 and T2 Sequences

Multi-slice T1 and T2 weighted images of the four low contrast disk inserts of the ACR MRI phantom were obtained using a 5 mm skip 5 mm slice thickness. The four low contrast resolution disks of varying thickness provide contrast levels of 1.4%, 2.5%, 3.6% and 5.1%, respectively. Each disk has 10 sets of holes varying in size from 7.0 mm to 1.5 mm, progressively. The number of complete sets that are resolved in each disk is added for a cumulative total low contrast resolution score.

### Results:

The following table summarizes the number of sets of holes (spokes) visible in each of the images and the corresponding total score.

|                           | Disk 1<br>Image #11 | Disk 2<br>Image #10 | Disk 3<br>Image #9 | Disk 4<br>Image #8 | Total<br>Score |
|---------------------------|---------------------|---------------------|--------------------|--------------------|----------------|
| ACR T1 Weighted Sequence  | 10                  | 10                  | 10                 | 8                  | 38             |
| ACR T2 Weighted Sequence  | 10                  | 10                  | 10                 | 6                  | 36             |
| Site T1 Weighted Sequence | 10                  | 10                  | 10                 | 6                  | 36             |
| Site T2 Weighted Sequence | 10                  | 10                  | 9                  | 2                  | 31             |

### Conclusion:

The low contrast resolution was found to be adequate. The total number of sets of holes that are resolved using ACR sequences should be at least 9 for systems with field strengths less than 3T, and at least 37 spokes for MRI systems with field strengths of 3T. Low contrast resolution is affected by signal-to-noise ratio (SNR) and phantom insert alignment. Factors affecting signal-to-noise ratio include general system calibration (resonance frequency, flip angles, etc.) gain, coil tuning, rf shielding, coil loading, image processing and scan parameters. Note that when slices are not perfectly centered on the low contrast disks, partial volume effects could influence these qualitative measurements.

## 12. MAGNETIC FIELD HOMOGENEITY EVALUATION

The Bandwidth-difference method<sup>1</sup> ( $\Delta BD$ ) was used to evaluate the magnetic field homogeneity (MFH). This method compares the image distortion using small and large bandwidth acquisitions to determine MFH.

**Phantom:** 32 cm Diameter Spherical Phantom (Blue)

**Test Protocol:** GRE Sequence, TR 50 msec, TE 10 msec, FA 25 degrees, 40 cm FOV, 256x256 Matrix, 1 Slice, Thickness 5 mm, NEX 1, BW1  $\pm$  2.00 kHz, BW2  $\pm$  31.25 kHz.

Images in all three planes were obtained using Gradient Echo (GRE) sequences with two different bandwidths. Spherical volume diameters were measured in the frequency encoding direction. Magnetic field homogeneity was calculated in parts per million (ppm) using the following equation:

$$\text{Homogeneity (ppm)} = [BW1 * BW2 *(x1 - x2)] / [CF*FOV*(BW2 - BW1)]$$

where, BW1 and BW2 are the two different bandwidths in Hz, x1 and x2 are the corresponding spherical volume diameter measurements in mm in the frequency encoding direction, FOV is the image field-of-view in mm, and CF is the resonant Center Frequency in MHz.

**Results:**

Frequency: 63.860670 MHz  
 Bandwidth 1:  $\pm$  2.00 kHz 4160 Hz  
 Bandwidth 2:  $\pm$  31.25 kHz 62500 Hz

|                            | Spherical Volume Diameter w/ BW1 | Spherical Volume Diameter w/ BW2 | Magnetic Field Homogeneity |
|----------------------------|----------------------------------|----------------------------------|----------------------------|
| Axial Plane (27 cm DSV)    | 321.0 mm                         | 316.0 mm                         | 0.9 ppm                    |
| Coronal Plane (27 cm DSV)  | 311.0 mm                         | 314.0 mm                         | 0.5 ppm                    |
| Sagittal Plane (27 cm DSV) | 318.0 mm                         | 314.0 mm                         | 0.7 ppm                    |

**Conclusion:**

Magnetic field homogeneity was found to be adequate at less than 1 ppm over a diameter of spherical volume of 27 cm.

<sup>1</sup> Chen et al., "Routine Testing of Magnetic Field Homogeneity on Clinical MRI systems", Med. Phys. 33, 4299-4306, (2006).

### 13. RF COIL PERFORMANCE EVALUATION

RF coil performance was evaluated using manufacturer provided phantoms of appropriate size and shape using a T1 weighted protocol:

**RF Coil 1:** Standard GE Head Coil  
**Phantom:** 17 cm GE Spherical Phantom w/ Loader

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 115 dB.

**Results:** Axial Orientation

| RF Coil               | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|-----------------------|-------------|------------|------------|------------|----------------|--------------|
| Standard GE Head Coil | 1024        | 1059.5     | 971.3      | 10.9       | 4.8            | 11.1         |

| RF Coil               | SNR | Percent Image Uniformity | Percent Signal Ghosting |
|-----------------------|-----|--------------------------|-------------------------|
| Standard GE Head Coil | 213 | 96%                      | 0.0%                    |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity was found to be adequate.

**RF Coil 2:** 8 Ch High Res Brain Array by MRI Devices  
**Phantom:** 17 cm GE Spherical Phantom w/o Loader

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 132 dB.

**Results:** Axial Orientation

| RF Coil                                 | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|-----------------------------------------|-------------|------------|------------|------------|----------------|--------------|
| 8 Ch High Res Brain Array by MRI Device | 1070        | 1333       | 909        | 15.2       | 2.9            | 16.1         |

| RF Coil                                 | SNR | Percent Image Uniformity | Percent Signal Ghosting |
|-----------------------------------------|-----|--------------------------|-------------------------|
| 8 Ch High Res Brain Array by MRI Device | 369 | 81%                      | 0.0%                    |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity was found to be adequate.

### 13. RF COIL PERFORMANCE EVALUATION (Continued)

RF coil performance was evaluated using manufacturer provided phantoms of appropriate size and shape using a T1 weighted protocol:

**RF Coil 3:** Integrated Body Coil  
**Phantom:** 32 cm GE Spherical Phantom (Blue)

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 36 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 158 dB.

**Results:** Axial Orientation

| RF Coil              | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|----------------------|-------------|------------|------------|------------|----------------|--------------|
| Integrated Body Coil | 262         | 271.6      | 247        | 22.0       | 10.7           | 23.0         |

| RF Coil              | SNR | Percent Image Uniformity | Percent Signal Ghosting |
|----------------------|-----|--------------------------|-------------------------|
| Integrated Body Coil | 24  | 95%                      | 0.2%                    |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity was found to be adequate.

**RF Coil 4:** 8 Ch Body Array by GE Full FOV  
**Phantom:** CTL Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 32 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 153 dB.

**Results:** Axial Orientation

| RF Coil                        | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|--------------------------------|-------------|------------|------------|------------|----------------|--------------|
| 8 Ch Body Array by GE Full FOV | ---         | 1842       | ---        | 18.9       | 3.8            | ---          |

| RF Coil                        | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|--------------------------------|-------------|--------------------------|-------------------------|
| 8 Ch Body Array by GE Full FOV | 491         | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity distribution and Maximum SNR values were found to be adequate.

### 13. RF COIL PERFORMANCE EVALUATION (Continued)

**RF Coil 5:** QUADKNEE T/R Knee-Foot Coil  
**Phantom:** GE 17 cm Diameter Spherical Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 103 dB.

**Results:** Sagital Orientation

| RF Coil                     | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|-----------------------------|-------------|------------|------------|------------|----------------|--------------|
| QUADKNEE T/R Knee-Foot Coil | ---         | 2117       | ---        | 8.8        | 3.6            | ---          |

| RF Coil                     | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|-----------------------------|-------------|--------------------------|-------------------------|
| QUADKNEE T/R Knee-Foot Coil | 588         | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity distribution and Maximum SNR values were found to be adequate.

**RF Coil 6:** HD TRknee PA  
**Phantom:** 12 cm Diameter Knee Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 111 dB.

**Results:** Axial Orientation

| RF Coil      | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|--------------|-------------|------------|------------|------------|----------------|--------------|
| HD TRknee PA | ---         | 8583       | ---        | 42.3       | 8.0            | ---          |

| RF Coil      | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|--------------|-------------|--------------------------|-------------------------|
| HD TRknee PA | 1068        | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity was found to be adequate.



### 13. RF COIL PERFORMANCE EVALUATION (Continued)

**RF Coil 7:** SHLDRPA4 Small Shoulder Coil  
**Phantom:** GE Small (10 cm Diameter) Spherical Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 18 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 147 dB.

**Results:** Axial Orientation

| RF Coil                      | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|------------------------------|-------------|------------|------------|------------|----------------|--------------|
| SHLDRPA4 Small Shoulder Coil | ---         | 8263       | ---        | 33.7       | 7.6            | ---          |

| RF Coil                      | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|------------------------------|-------------|--------------------------|-------------------------|
| SHLDRPA4 Small Shoulder Coil | 1090        | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity distribution and Maximum SNR values were found to be adequate.

**RF Coil 8:** SHLDRPA4 Large Shoulder Coil  
**Phantom:** GE 17 cm Diameter Spherical Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 142 dB.

**Results:** Axial Orientation

| RF Coil                      | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|------------------------------|-------------|------------|------------|------------|----------------|--------------|
| SHLDRPA4 Large Shoulder Coil | ---         | 5197       | ---        | 36.4       | 6.7            | ---          |

| RF Coil                      | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|------------------------------|-------------|--------------------------|-------------------------|
| SHLDRPA4 Large Shoulder Coil | 776         | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity distribution and Maximum SNR values were found to be adequate.

### 13. RF COIL PERFORMANCE EVALUATION (Continued)

RF coil performance was evaluated using manufacturer provided phantoms of appropriate size and shape using a T1 weighted protocol:

**RF Coil 9:** 8ch CTL Spine Array Coil CTL123

**Phantom:** GE CTL Phantom

**Pulse Sequence:**

Spin Echo, TR 300, TE 20, 1 NEX, FA 90, 5 x 5 mm Slice Thickness, 25 cm FOV, 256x256 matrix, BW ± 15.63 kHz, 1:23 Scan Time, Transmitter Gain 143, 142 and 142 dB, respectively.

**Results:** Axial Orientation

| RF Coil                         | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|---------------------------------|-------------|------------|------------|------------|----------------|--------------|
| 8ch CTL Spine Array Coil CTL123 | ---         | 2596       | ---        | 28         | 6.0            | ---          |

| RF Coil                         | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|---------------------------------|-------------|--------------------------|-------------------------|
| 8ch CTL Spine Array Coil CTL123 | 436         | n/a                      | n/a                     |

| RF Coil | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|---------|-------------|------------|------------|------------|----------------|--------------|
| CTL345  | ---         | 3378       | ---        | 33         | 7.1            | ---          |

| RF Coil | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|---------|-------------|--------------------------|-------------------------|
| CTL345  | 477         | n/a                      | n/a                     |

| RF Coil | Mean Signal | Max Signal | Min Signal | Bkg Signal | Bkg S.D. Noise | Ghost Signal |
|---------|-------------|------------|------------|------------|----------------|--------------|
| CTL456  | ---         | 3132       | ---        | 26         | 5.8            | ---          |

| RF Coil | Maximum SNR | Percent Image Uniformity | Percent Signal Ghosting |
|---------|-------------|--------------------------|-------------------------|
| CTL456  | 536         | n/a                      | n/a                     |

**Conclusion:**

No significant image artifact or ghosting was noted in reconstructed images. Image uniformity distribution and Maximum SNR values were found to be adequate.

## 14. SOFT COPY DISPLAY EVALUATION

**Luminance Meter Make/Model:** Unfors Xi Photometer

**Soft Copy SMPTE Pattern Evaluation:**

1. The 5% and the 95% square contrast patterns were properly resolved and visualized.
2. Each gray-level step from 0% to 100% was uniform and distinct from the adjacent step.
3. The borders and lines of the SMPTE pattern were straight.
4. No spatial distortions or misalignments were noted in the grids across the screen.
5. Alphanumeric characters looked sharp and focused.
6. The high contrast line-pair resolution patterns in the center and corners of the display area were linear, properly resolved and adequately visualized without any magnification.
7. No streaking was noted in and around the white and black rectangular patterns.

The overall appearance of the SMPTE pattern was found to be adequate. The soft copy display monitor resolution, linearity, contrast, spatial accuracy and distortion were found to be adequate.

**Soft Copy Display Luminance Measurements (cd/m<sup>2</sup>):**

| Operator Console                            | Display | Top  | Top   | Bottom | Bottom |                   |
|---------------------------------------------|---------|------|-------|--------|--------|-------------------|
| NEC Multisync EA192M LCD                    | Center  | Left | Right | Left   | Right  | Units             |
| Luminance Measurements in cd/m <sup>2</sup> | 100     | 97   | 90    | 101    | 94     | cd/m <sup>2</sup> |

| Operator Console                            | Maximum Luminance     | Minimum Luminance      | Luminance Uniformity |
|---------------------------------------------|-----------------------|------------------------|----------------------|
| NEC Multisync EA192M LCD                    | Center Display        | Center Display         | Percent Difference   |
| Luminance Measurements in cd/m <sup>2</sup> | 100 cd/m <sup>2</sup> | 0.35 cd/m <sup>2</sup> | 11%                  |

**Conclusion:**

Maximum and minimum luminance of the display monitor as well as the luminance uniformity were found to be adequate. The maximum luminance of diagnostic quality monitor should exceed 90 cd/m<sup>2</sup>, the minimum luminance should be less than 1.2 cd/m<sup>2</sup> and the luminance uniformity depicted by the percent difference in the maximum luminance values measured in the image display area should be less than or equal to 30%.

## 15. EVALUATION OF SITE'S TECHNOLOGIST QC PROGRAM

Technologist QC program is well established using the GE QC Phantom. Magnet Helium boiloff and pressure is also monitored.

| Technologist QC Procedures                             | PASS/FAIL/NA |
|--------------------------------------------------------|--------------|
| 1. Center Frequency and Transmitter Gain Check (Daily) | PASS         |
| 2. Artifact Evaluation (Daily)                         | PASS         |
| 3. SNR measurement (Daily)                             | PASS         |
| 4. Visual Checklist (Monthly)                          | Recommended  |

**Conclusion:**

Technologist QC program is well established. Daily QC procedures and SNR measurements are being properly performed and documented.

## 16. ASSESSMENT OF MRI SAFETY PROGRAM

- a. High magnetic field warning signs are properly posted. Access to Safety Zone III (Control Area) is limited to authorized personnel and controlled by lock and key. Access to Safety Zone IV (MRI Scanner Room) was also properly posted with a High Magnetic Field warning sign.
- b. MRI Safety Policy & Procedures are available on file.

| MRI Safety Policies and Procedures address the following subjects: |                                                           | YES/NO/NA |
|--------------------------------------------------------------------|-----------------------------------------------------------|-----------|
| 1.                                                                 | Designated MR safety officer                              | Yes       |
| 2.                                                                 | Site access restrictions (MR zones)                       | Yes       |
| 3.                                                                 | Documented MR Safety education/training for all personnel | Yes       |
| 4.                                                                 | Patient and non-MR personnel screening                    | Yes       |
| 5.                                                                 | Pediatric patients                                        | N/A*      |
| 6.                                                                 | Magnet quench                                             | Yes       |
| 7.                                                                 | Cryogen safety                                            | Yes       |
| 8.                                                                 | Acoustic noise                                            | Yes       |
| 9.                                                                 | Pregnant patients and staff                               | Yes       |
| 11.                                                                | Contrast agent safety                                     | Yes       |
| 12.                                                                | Sedations                                                 | Yes       |
| 13.                                                                | Thermal burns                                             | Yes       |
| 14.                                                                | Emergency code procedures                                 | Yes       |
| 15.                                                                | Device and object screening                               | Yes       |
| 16.                                                                | Designation of MR safe/MR conditional status              | Yes       |
| 17.                                                                | Reporting of MR safety incidents or adverse incidents     | Yes       |
| 18.                                                                | Patient communication                                     | Yes       |
| 19.                                                                | Infection control and medical waste                       | Yes       |

| ACR Criteria for Compliance: |                                                                                      | YES/NO/NA |
|------------------------------|--------------------------------------------------------------------------------------|-----------|
| 1.                           | Written policies are present and readily available to facility staff.                | Yes       |
| 2.                           | Written policies are reviewed and updated on a regular basis.                        | Yes       |
| 3.                           | Facility has appropriate MR safety warning signage and methods of controlled access. | Yes       |

Overall Status: Pass/Fail

Pass

Note:

\*Pediatric patient scans are generally not performed.













