RF Coil Testing - The Simply Physics way

As part of the 2019 AAPM meeting I was invited to give a talk on RF Coil testing. Like most speakers, I will be uploading my PowerPoint slides (probably at the tail end of this document). However, there are a LOT of slides… with lots of pictures and not a lot of words. They are meant to support my speaking and not necessarily stand on their own. Therefore, I am beginning with this textual description of my basic philosophy/approach to RF coil testing. Read this and then start in on the slides.

Qualifications
Just so that whoever reads this understands my background from which I have based the opinions expressed in this document:

1) I started my Ph.D work in MRI in 1985 (USC - Surface Coil Intensity Correction of Endo-Rectal Prostate Images)
2) Post graduation I developed imaging sequences for Elscint for one year and then headed Picker’s Cardiac MRI R&D program for roughly 5 years.
3) I was on the radiology faculty at the University of Maryland Med School for 10 years.
4) I wrote the introductory textbook “All You Really Need to Know About MRI Physics”.
5) I have been providing MRI QA services since 2001.
6) I was (and am) on the ACR MRI Physics Subcommittee for many years and was active in writing the ACR’s MRI Quality Control manual in which I made major contributions to the RF coil testing and Magnet homogeneity testing sections.
7) As of June, 2019 I have conducted over 1500 annual performance reviews or acceptance tests including systems from every major MRI vendor.
8) I have performed over 35,000 RF coil tests on 5800 separate RF coils.

Basic Assumptions or Testing Principals
Over the 19 years that I have been testing scanners I have identified several important principals regarding the best design of RF coil and magnet homogeneity testing sequences. I have written several white papers and one RSNA poster (all of which are available upon request) that go into more details regarding these principals but I shall summarize the conclusions here.
RF Coil Testing

1) The single most important requirement for good SNR measuring is REPRODUCIBILITY. In particular:
   a) Reproducibly positioning the phantom in the coil and the combination in the magnet.
   b) Reproducibly choosing the imaging slice(s) location.
   c) Reproducibly measuring the signal mean in the phantom (drawing and positioning the ROI).
   d) Reproducibly measuring the background noise.

2) When measuring the Signal to Noise Ratio (SNR) it is easy to measure the signal, the values are typically large in amplitude and it does NOT take a large number of pixels to obtain a reasonable estimate of the mean.

3) Measuring noise is the more challenging task. Because it is typically a small number in the denominator of the SNR, small errors in the estimate of the noise can have a large affect on the SNR. Problems associated with noise measurements include:
   a) Spatially varying (usually due to geometric distortion correction and/or adaptive combination of channel data.
   b) Ghosting and/or wrap around in PE direction
   c) RF noise lines
   d) Limited # of pixels available to make the measurements
   e) All MR images are integer. When the background noise has a low amplitude the noise pixels are often truncated (or rounded) to a limited number of values, i.e. 0, 1 & 2. This makes it very difficult to get a good estimate of variance of the Rayleigh distribution.

4) In addition to the above consider this. A typical 256x256 image has 64K pixels. At the very least I want no more than half of those pixels used for measuring the signal mean, more typically only 1/3rd to 1/5th thereby leaving potentially 1/2 to 4/5th of the pixels available for measuring the noise. Keep in mind that not all of the noise pixels may be available for measuring due to ghosting or other artifacts.

5) Keeping the above in mind, I make the following choices when designing a test imaging protocol:
   a) Choose a FOV that is roughly twice the diameter of the phantom in the phase encode (PE) direction thereby minimizing the chance of ghosting wrapping around into the phantom. Additionally, if using a spherical phantom this results in a 4:1 ratio of noise pixels to signal pixels. With a square phantom it is a 3:1 ratio.
   b) Choose a thin slice thickness, often the thinnest slice that the system is capable of obtaining, somewhere between 1mm and 3mm. This increases the background noise level. (Yes, the measured SNR is low, but it is REPRODUCIBLE!)
   c) Similarly, choose a moderately high receiver BW. For 0.7T systems and higher I have settled on 244 Hz/pixel which corresponds to 31.2 KHz on GE systems or 62 KHz on most other systems.
   d) Choose a moderately short TR. I have settled on 200 msec. This results in shorter scan times and lower SNR (again, increasing the relative background noise.)
   e) I use a 256 x 256 matrix. Yes, 256 x 128 is faster but it would reduce the background noise by 40% when we want to increase the noise. It would also result in the acquisition of asymmetric pixels which I am never a fan of.
   f) Whenever possible, I turn off ALL post-processing filters especially Geometric Distortion correction which results in the the background noise becoming spatially variant.
g) When testing phased array coils I choose vector combination (square root of the sum of the squares) instead of adaptive combination.

h) I run every sequence twice. This allows the option of using the NEMA subtraction method and also helps to identify intermittent behavior.

6) When analyzing the images my automated analysis software does the following:
   a) It uses thresholding to identify all the edges of the phantom defining an ROI that includes ALL of the phantom and then shrinks the ROI by 4 pixels all around to help avoid edge artifacts. This is an EXTREMELY reproducible method of measuring the signal mean since it does not depend on positioning a small ROI in a non-uniform signal phantom.
   b) It starts with the original thresholded ROI of the phantom and then expands it by 5 pixels to define an exclusion region and then uses ALL of the rest of the pixels in the image to determine the noise region. The software then analyzes the noise to exclude pixels that are most likely affected by ghosting or roll-off filtering at the edge of the image or other types of artifacts.
   c) The underlying sigma of the background noise is estimated from the Std Dev of the noise, from the Mean of the noise and from the Std Deviation of the pixels used for calculating the signal mean after subtracting the two repeats. (NEMA method). The ‘goodness’ of the estimate can be evaluated by looking at the ratio of the Mean of the noise to the Std Dev of the noise which should follow a well defined pattern depending upon the number of receiver channels.
   d) The SNR is reported using all three estimates of sigma. Typically, the NEMA method results in an SNR value much lower than the others due to poor subtractions caused by either ghosting or swirling of the fluid in the phantom and is ignored. Therefore, I typically focus on the average of the non-NEMA SNR results.

7) When testing Phased Array (PA) coils it is imperative that ALL channels be evaluated individually but preferably from a SINGLE scan. This requires that a phantom be used that is large enough to cover the sensitive volume of each channel at one time.

8) Sometimes the phantom is large enough but no one imaging plane properly evaluates all of the channels. In such circumstances using both a sagittal and a coronal sequence (separately of course) going through the middle of the phantom is preferred to using multiple axial planes because it is very difficult to ensure reproducible axial slice positioning from year to year. Typical examples would be NVA, CTL Spine, Foot/Ankle and Wrist coils.

9) Finally, when testing a PA coil with an unknown coil configuration, I always look for symmetry between pairs of coil. There should ALWAYS be L/R symmetry, often A/P symmetry as well.

Magnet Homogeneity Testing (bonus section)

1) The only way to measure magnet homogeneity is with the Phase Difference method. FWHM of an FID spectrum or changes in geometry with different receiver BWs are both useless.

2) Two 3D sequences with a spherical phantom is preferred over 2D sequences because 2D sequences require 3 pairs of scans in the Axial, Coronal and Sagittal planes.

3) This requires that the scanner either output a set of Phase Difference image or that it provides EITHER a pair of Real and Imaginary images or Magnitude and Phase images. (I have written software that can perform the phase subtraction and unwrapping of the difference images, both 3D and 2D)

4) The spherical phantom should be as large as possible. I use the 32 cm diameter sphere that comes with every GE scanner. (30 cm diameter is OK, 24 cm is not.)
5) The sphere should be placed directly on the scan table or on a stack of unused printer paper, NEVER with a plastic support ring. For some reason, every support ring I have ever seen used has caused a localized distortion of the field. (And the toner used in all laser printers is ferromagnetic so you never want to use paper with printing on it.)

6) Color coded contour maps of the field in slices in all three orthogonal planes are useful for identifying localized distortions in the magnetic field caused by either bad shims or metal in the magnet.

Best Method to Estimate Noise (sigma)?
While preparing our presentations there was some limited communication between the various speakers. It became apparent that there was some differences of opinion as to what was the best method for measuring the SNR, or more precisely, the best method to estimate the variance of the background noise, the denominator of the Signal-to-Noise ratio. Some advocated for the NEMA subtraction method. I, on the other hand, am convinced that using the mean of the air pixels is the most reliable.

I hope to one analyze the 35,000+ RF coil tests that I have in my database to unequivocally answer that question. For the moment, I have chosen 3 magnets at 3 sites, 1 GE, 1 Siemens and 1 Philips, where I have 5 to 6 years of good data (consistent coils, consistent phantoms and consistent protocols) and looked at how the year to year SNR values of all of their RF coils change. I threw out any data points where I identified a problem with the coil (bad channel, artifacts in the background, etc.). Below are three tables summarizing those data. In addition to the three methods of estimating sigma, I looked at the variation of taking the average of the SNR produced using the Std Dev and the Mean of the background pixels, ignoring the NEMA method.

<table>
<thead>
<tr>
<th>GE Magnet  N = 17</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEMA</td>
<td>Air S.D.</td>
<td>Air Mean</td>
<td>Average</td>
</tr>
<tr>
<td>Average % deviation</td>
<td>4.46%</td>
<td>2.66%</td>
<td>2.58%</td>
<td>2.59%</td>
</tr>
<tr>
<td>Std Dev of % deviations</td>
<td>3.21%</td>
<td>1.43%</td>
<td>1.58%</td>
<td>1.50%</td>
</tr>
<tr>
<td># of times this method best</td>
<td>5</td>
<td>3</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Philips Magnet  N = 22</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NEMA</td>
<td>Air S.D.</td>
<td>Air Mean</td>
<td>Average</td>
</tr>
<tr>
<td>Average % deviation</td>
<td>9.63%</td>
<td>4.09%</td>
<td>3.91%</td>
<td>3.88%</td>
</tr>
<tr>
<td>Std Dev of % deviations</td>
<td>7.83%</td>
<td>1.96%</td>
<td>2.13%</td>
<td>2.03%</td>
</tr>
<tr>
<td># of times this method best</td>
<td>3</td>
<td>6</td>
<td>12</td>
<td>2</td>
</tr>
</tbody>
</table>
And here are plots of the SNR variations for all of the coils tests:
From these data we can see that while there is little absolute difference between estimating the sigma from the air pixels, using the mean is consistently a little better. Using the NEMA subtraction method works when things are absolutely perfect but if there is any swirling of the phantom liquid or ghosting in the system then the SNR results can fail miserably. Personally, I most often report the average value.

I hope you have found this useful.

Moriel NessAiver, Ph.D.
moriel@simplyphysics.com
RF Coil Testing
Ins & Outs and Ups & Downs

Moriel NessAiver, Ph.D.

SimplyPhysics
the home of MRI physics put simply

www.simplyphysics.com
My Qualifications

- Doing MRI since 1985
- Worked in industry for 6 years
- Worked in Academia for 10 years
- Started QA testing in 2001
- Have conducted over 1500 annual performance reviews (about 120/yr now)
- Have tested over 5800 individual RF coils
- For a total of >35,500 separate tests
How often do I find problems?

Out of 800 Yearly Performance Evaluations on 1.5T and 3T GE, Siemens and Philips scanners I found problems at 472, or 59% of every site visit.

- One or more bad RF coils (≈15% of all coils)
- Magnet Homogeneity
- Gradient Calibration
- System wide artifacts (RF Noise lines or ghosting)
- Soft Copy Display (no clinical affect)
How often do others find problems?

<table>
<thead>
<tr>
<th>Coil</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>% change 2013</th>
<th>% change 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flex Large 2ch</td>
<td>598</td>
<td>1552</td>
<td>998</td>
<td>160%</td>
<td>-36%</td>
</tr>
<tr>
<td>Flex Medium 2ch</td>
<td>520</td>
<td>4626</td>
<td>1005</td>
<td>790%</td>
<td>-78%</td>
</tr>
<tr>
<td>SENSE Body 4ch</td>
<td>2258</td>
<td>1781</td>
<td>1726</td>
<td>-21%</td>
<td>-3%</td>
</tr>
<tr>
<td>Head/Neck 3ch</td>
<td>956</td>
<td>5729</td>
<td>907</td>
<td>499%</td>
<td>-84%</td>
</tr>
<tr>
<td>SENSE Spine 123 3ch</td>
<td>4147</td>
<td>2569</td>
<td>1035</td>
<td>-38%</td>
<td>-60%</td>
</tr>
<tr>
<td>SENSE Spine 345 3ch</td>
<td>2208</td>
<td>2420</td>
<td>948</td>
<td>9.6%</td>
<td>-61%</td>
</tr>
<tr>
<td>Flex Large 2ch</td>
<td>1154</td>
<td>495</td>
<td>1267</td>
<td>-57%</td>
<td>156%</td>
</tr>
<tr>
<td>SENSE Torso 6ch</td>
<td>1168</td>
<td>1866</td>
<td>456</td>
<td>60%</td>
<td>-76%</td>
</tr>
</tbody>
</table>

Reported SNR Values

ACR
• Volume Coils
• Surface Coils

Simply Physics
• Volume Coils – 1 ch
  ○ Body, Head, Knee, Wrist
• Surface Coils – 1 ch
  ○ Simple Loops, Flex Coils
• Phased Array Coil
  ○ Everything Else!
Types of RF Coils

Quintessential Volume Coil

PIU = 96.0%

Quintessential Surface Coil
Types of RF Coils

Quintessential Volume Coil
Quintessential Surface Coil

Background
sort of uniform
Types of RF Coils

Quintessential Surface Coil

Signal profile through green line
Types of RF Coils

Quintessential Surface Coil

Signal profile through green line

Background sort of uniform
Types of RF Coils

8 Channel Phased Array Head Coil - Volume or Surface?

PURE
PIU = 94.3%

No PURE
PIU = 75.4%
Types of RF Coils

8 Channel Phased Array Head Coil - Volume or Surface?

PURE

Spatially varying noise

No PURE

Moderately Uniform Noise

Most image processing methods adversely affect background noise.
Questions to be answered:

- What is the single most important concept in RF Coil Testing?
- When measuring the SNR of any RF coil, is it more important to improve the accuracy of the signal or the noise?
- What is the best way to measure the SNR of a surface coil?
REPRODUCIBILITY

- Documenting the type of phantom used
  - Match the phantom size/shape to the coil’s sensitive volume

- Positioning the phantom in the coil
  - Securely position in center of sensitive volume

- Location of imaging slice(s) through the phantom
  - Easily identified reference position
  - Be sure to cover sensitive volume of every channel
  - May need multiple planes
REPRODUCIBILITY

- Scan parameters
  - Try to use the the exact same protocol each time. (But what if you don’t?)
  - Design the sequence to maximize reliability (reproducibility) of SNR value.

- Analysis – Drawing the ROIs
  - Signal ROI – Almost all of the phantom!
  - Noise ROI – All of the air without ghosting or artifacts
Defining SNR

\[ \frac{P_{\text{pixels}}}{\sigma_{\text{sigma}}} \]
Measuring SNR is Complex

Image Pixel ➔ Magnitude of Complex FFT

\[ P = \sqrt{(R \pm \sigma)^2 + (I \pm \sigma)^2} \]

**Set** \( I = \emptyset \)

\[ P = \sqrt{R^2 \pm 2R\sigma + 2\sigma^2} \]
Signal = Mean of (P) and has Rician Distribution

\[
P = \sqrt{R^2 \pm 2R\sigma + 2\sigma^2}
\]

If \( R \gg \sigma \)

\[
P = |R| \pm \sigma
\]
Measuring the Signal is Easy - Theoretically

Signal = Mean of (P) and has Rician Distribution

\[ P = \sqrt{R^2 \pm 2R\sigma + 2\sigma^2} \]

If \( R \gg \sigma \)

\[ P = |R| \pm \sigma \]
Measuring the Signal is Easy - Theoretically

Signal = Mean of (P) and has Rician Distribution

Signal Distribution with SNR of 1, 2, 3, 4 & 5
Actually Measuring the Signal

Rician Distribution convolved with Sensitivity Profile

Signal Histogram with 97.2% Uniformity

1150 1200 1250 1300 1350 1400
Actually Measuring the Signal

Rician Distribution convolved with Sensitivity Profile

Actually Measuring the Signal

Rician Distribution convolved with Sensitivity Profile

15% threshold
4 pixel shrink

Histogram of Signal in 8ch Head Coil

Actually Measuring the Signal

Measuring the Signal of Surface Coils

- ACR says to draw small ROI at high signal point.
- Small change in ROI location or size can make big change in signal.

6% delta
Actually Measuring the Signal

Measuring the Signal of Surface Coils

- Draw an ROI including **ALL** of the phantom signal.
- Last 4 yrs of SNR values:
  
  182, 179, 174, 180
  
  \[178.8 \pm 3.4 \text{ (1.9\%)}\]
Actually Measuring the Signal

Measuring the Signal of Surface Coils

All of these surface coils should use a simple circular ROI.
Actually Measuring the Signal

Measuring the Signal of Surface Coils

Simple Square

3% Threshold
4 pixel shrink
What about odd shaped phantoms?

2 squares

Polygon

2% Threshold
4 pixel shrink
My Rule of Thumb for Measuring the signal.

- The phantom should take up about 20% of the FOV.

- If 256 x 256 pixels then 20% of 64K = 12-15K pixels
What about the Noise (\(\sigma\))?

Noise has Rayleigh distribution (floating point)

\[
\sigma = SD_{meas}/0.655
\]

or

\[
\sigma = Mean_{meas}/1.253
\]
1) Images are Integer – Do they truncate or round?

**What Can Affect the Noise?**

- **True Sigma**
  - Rounding Used
  - From SD
  - From Mean

- **Measured S.D or Mean**
  - Rounding Used
  - From SD
  - From Mean
What Can Affect the Noise?

1) Images are Integer – Do they truncate or round?

1) Images are Integer – Do they truncate or round?

However...

The true mean = measured mean + 0.5
What Can Affect the Noise?

True Mean = Measured Mean + 0.5

2) Almost any filter

- Basic Rayleigh Distribution
  - Mean=1.25
  - S.D. = 0.655
- 3x3 Smoothing Filter
  - Mean=1.25
  - S.D. = 0.220
What Can Affect the Noise?

3) Geometric Distortion Correction
What Can Affect the Noise?

3) Geometric Distortion Correction

- Non-corrected image
  - $\text{SNR}_{\text{S.D.}} = 249$
  - $\text{SNR}_{\text{Mean}} = 225$
  - $\text{SNR}_{\text{NEMA}} = 198$

- Distortion corrected image
  - $\text{SNR}_{\text{S.D.}} = 137$
  - $\text{SNR}_{\text{Mean}} = 216$
  - $\text{SNR}_{\text{NEMA}} = 231$

S.D. = 3.6
Mean = 19.3

S.D. = 6.5
Mean = 20.0
4) NEMA method to estimate noise – SWIRLING!

- Run the scan twice
- Subtract the 2nd image from the 1st.
- Measure S.D. in Phantom

\[ \sigma \approx S.D. \times \sqrt{2} \]
What Can Affect the Noise?

5) Signal Intensity Correction or Normalization

What Can Affect the Noise?

5) Signal Intensity Correction or Normalization

What Can Affect the Noise?

5) Signal Intensity Correction or Normalization

Mean Noise Values

A = 13.0
B = 14.4
C = 16.8
D = 18.6
E = 20.7
F = 21.8
What Can Affect the Noise?

6) Adaptive Coil Combination

- Head 8ch
- NVA 8ch
- Spine 1/2
- Breast 7ch
- Cardiac 5ch
- Wrist 8ch
What Can Affect the Noise?

6) Adaptive Coil Combination

Mean / Std. Dev

9.1 / 3.7
7.6 / 5.8
3.7 / 3.8
10.5 / 9.3
7) Adaptive Coil Combination Compared to Vector Sum

What Can Affect the Noise?

8 Channels to be combined

Adaptive

Vector
What Can Affect the Noise?

7) Adaptive Coil Combination Compared to Vector Sum

Philips’ Software V3.2.2

Adaptive

Vector

Philips’ Software V5.3.0

CLEAR

Vector

Background set to ZERO

Only noise is GHOST

What Can Affect the Noise?

8) RF Noise lines (and other artifacts)
What Can Affect the Noise?

8) RF Noise lines (and other artifacts)
9) Unknown and weird filtering!

The Philips images had close to **29,000** pixels set to exactly Zero!

The S.D. was greater than the mean!
Test EVERY channel of EVERY phased array (PA) coil

- SNR $\propto \sqrt{(#\text{channels})}$
- Affects image uniformity
- Large affect on parallel imaging techniques
- Client paid for ALL channels to be working

<table>
<thead>
<tr>
<th># channels</th>
<th>signal drop for 1 dead channel</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>29.3%</td>
</tr>
<tr>
<td>4</td>
<td>13.4%</td>
</tr>
<tr>
<td>8</td>
<td>6.5%</td>
</tr>
<tr>
<td>16</td>
<td>3.2%</td>
</tr>
<tr>
<td>32</td>
<td>1.6%</td>
</tr>
</tbody>
</table>
8 Ch Head PA Coil – Example

Channel #4 is dead

Mean: 847
Air M: 8.29
Airsd: 1.64

SNR = 280
PIU = 78.4%

Same coil - repaired

Mean: 1035
Air M: 9.60
Airsd: 1.88

SNR = 295
PIU = 81.0%

8 Ch Body Array Coil – Example

SNR: 98.8

SNR: 95.6

Bad Channel
Channel # 3 is dead!

SNR: 95.6
18 Ch Body Array Coil – Example

SNR: 206.4

SNR: 200.6

Where is the Bad Channel?
18 Ch Body Array Coil – Example

SNR: 16.1  SNR: 4.6  SNR: 21.0  SNR: 3.3

Siemens Channel B14

Siemens Channel B34

TWO Bad Channels!
16 Ch Head/Neck/Spine – Example

Can you tell the difference?

SNR: 211
Mean: 2037
ROI Area: 339.07
2017

SNR: 189
Mean: 2074
ROI Area: 339.99
2018

SNR: 198
Mean: 2499
ROI Area: 339.37
2019

Air M: 61.15
Airsd: 8.24
Airm2: 61.70

Air M: 67.95
Airsd: 9.62
Airm2: 68.62

Air M: 80.48
Airsd: 10.75
Airm2: 81.19

Each year a different channel went bad.
Is there really any difference?
9 Ch Spine Table – Example

SNR:109

SNR:107

Yes!
### Measuring the Signal

- Signal Mean is EASY
- Signal area ≈ 1/3 to 1/5 of FOV.
- ROI includes whole phantom to average out non-uniformity.

### Measuring the Noise

- Sigma of Noise is harder.
- Area ≈ 2/3 to 4/5 of FOV
- Must avoid artifacts
- Want spatially uniform
My Scan Parameters

- TR / TE = 200 / 20
- BW = 244 Hz/pixel (31.25 KHz on GE, 62.5 KHz on others)
- Matrix = 256 x 256
- FOV ≈ Twice the phantom diameter in PE direction
- With large phantoms sometimes use NPW (anti-aliasing)
  - Phase encode in the long direction to leave AIR in Frequency direction
- Slices as thin as possible
  - @ 1.5T and 3T use 1.0 to 2.0
  - @ Lower fields usually no higher than 3 mm
  - Real low SNR coils on open magnets use 5 or even 10 mm
Questions to be answered:

- What is the single most important concept in RF Coil Testing?
- When measuring the SNR of any RF coil, is it more important to improve the accuracy of the signal or the noise?
- What is the best way to measure the SNR of a surface coil?
1st Question: What is the single most important concept in RF Coil testing?

REPRODUCIBILITY

- Document your setup (take pictures)
- Choose you slice location well.
- Include complete phantom in your ROI
2nd Question: When measuring the SNR of any RF coil, is it more important to improve the accuracy of the signal or the noise?

Short Answer: The noise

- You want both to be accurate.
- Noise is harder to measure.
- Design your sequence to provide lots of space to measure the noise.
- Design your sequence to avoid integer truncation problems.
3rd Question: What is the best way to measure the SNR of a surface coil?

- Match the size of the phantom to the sensitive volume of the coil.
- Use a FOV twice the diameter of the phantom.
- Measure the signal by including ALL of the phantom.
- Measure the noise in the frequency encode direction.
## Final Question – What Method is Best?

<table>
<thead>
<tr>
<th>Method</th>
<th>NEMA</th>
<th>StdDev of Air</th>
<th>Mean of Air</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE Magnet N=19</td>
<td>4.97%</td>
<td>2.50%</td>
<td>2.29%</td>
</tr>
<tr>
<td>Average % deviations</td>
<td>2.34%</td>
<td>1.40%</td>
<td>1.40%</td>
</tr>
<tr>
<td>Std Dev of % deviations</td>
<td>3.63%</td>
<td>1.30%</td>
<td>1.46%</td>
</tr>
<tr>
<td># time this method best</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Philips Magnet N=22</td>
<td>9.63%</td>
<td>4.09%</td>
<td>3.85%</td>
</tr>
<tr>
<td>Average % deviations</td>
<td>7.83%</td>
<td>1.96%</td>
<td>2.13%</td>
</tr>
<tr>
<td>Std Dev of % deviations</td>
<td>4.09%</td>
<td>1.96%</td>
<td>2.13%</td>
</tr>
<tr>
<td># time this method best</td>
<td>3</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Siemens N=27</td>
<td>6.82%</td>
<td>4.71%</td>
<td>3.45%</td>
</tr>
<tr>
<td>Average % deviations</td>
<td>3.97%</td>
<td>2.45%</td>
<td>3.45%</td>
</tr>
<tr>
<td>Std Dev of % deviations</td>
<td>4.08%</td>
<td>3.21%</td>
<td>2.18%</td>
</tr>
<tr>
<td># time this method best</td>
<td>3</td>
<td>7</td>
<td>17</td>
</tr>
</tbody>
</table>
Final Question – What Method is Best?

NEMA?  StdDev of Air??  Mean of Air???

% deviations over 6 years of 19 different RF coil tests - GE

- NEMA
- Air SD
- Air Mean
- Average

Final Question – What Method is Best?

NEMA?  StdDev of Air??  Mean of Air???

% deviations over 5 years of 22 different RF coil tests - Philips

- NEMA
- Air SD
- Air Mean
- Average
Final Question – What Method is Best?

% deviations over 5 years of 27 different RF coil tests. - Siemens

- Siemens

NEMA? StdDev of Air?? Mean of Air???
Phased Array Coil – Case Study

Siemens Verio (3T) Spine Coil  (example of good)

Yearly Composite SNR values

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP12</td>
<td>105</td>
<td>96</td>
<td>103</td>
<td>106</td>
</tr>
<tr>
<td>SP34</td>
<td>102</td>
<td>95</td>
<td>102</td>
<td>104</td>
</tr>
<tr>
<td>SP56</td>
<td>102</td>
<td>99</td>
<td>102</td>
<td>105</td>
</tr>
<tr>
<td>SP78</td>
<td>103</td>
<td>99</td>
<td>102</td>
<td>105</td>
</tr>
</tbody>
</table>
**Phased Array Coil – Case Study**

### Siemens Verio (3T) Spine Coil

<table>
<thead>
<tr>
<th></th>
<th>SP12</th>
<th>SP34</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yearly Composite SNR values</strong></td>
<td><strong>2015</strong></td>
<td><strong>2016</strong></td>
</tr>
<tr>
<td>SP12</td>
<td>121</td>
<td>127</td>
</tr>
<tr>
<td>SP34</td>
<td>93</td>
<td>90</td>
</tr>
<tr>
<td>SP56</td>
<td>120</td>
<td>126</td>
</tr>
<tr>
<td>SP78</td>
<td>122</td>
<td>125</td>
</tr>
</tbody>
</table>
Phased Array Coil – Case Study

Siemens Verio (3T) Spine Coil

SP12
Noise Mean = 19.3

SP34
Noise Mean = 28.4

Yearly Composite SNR values

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP12</td>
<td>121</td>
<td>127</td>
<td>118</td>
<td>120</td>
</tr>
<tr>
<td>SP34</td>
<td>93</td>
<td>90</td>
<td>95</td>
<td>92</td>
</tr>
<tr>
<td>SP56</td>
<td>120</td>
<td>126</td>
<td>119</td>
<td>119</td>
</tr>
<tr>
<td>SP78</td>
<td>122</td>
<td>125</td>
<td>121</td>
<td>122</td>
</tr>
</tbody>
</table>
Phased Array Coil – Case Study

Siemens Verio (3T) Spine Coil

Siemens Test Image

Siemens QA Test Results: Spec > 30

<table>
<thead>
<tr>
<th></th>
<th>SP1</th>
<th>SP2</th>
<th>SP3</th>
<th>SP4</th>
<th>SP5</th>
<th>SP6</th>
<th>SP7</th>
<th>SP8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Test</td>
<td>44.5</td>
<td>43.0</td>
<td>37.0</td>
<td>32.8</td>
<td>45.9</td>
<td>44.1</td>
<td>47.1</td>
<td>47.3</td>
</tr>
</tbody>
</table>

Siemens measures one composite image at each coil position. However, each coil position actually consists of 3 channels.
Siemens Verio (3T) Spine Coil

All channels pass!

Siemens Test Image

<table>
<thead>
<tr>
<th></th>
<th>SP1</th>
<th>SP2</th>
<th>SP3</th>
<th>SP4</th>
<th>SP5</th>
<th>SP6</th>
<th>SP7</th>
<th>SP8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Test</td>
<td>44.5</td>
<td>43.0</td>
<td>37.0</td>
<td>32.8</td>
<td>45.9</td>
<td>44.1</td>
<td>47.1</td>
<td>47.3</td>
</tr>
<tr>
<td>New Coil</td>
<td>46.9</td>
<td>44.5</td>
<td>46.4</td>
<td>44.9</td>
<td>49.9</td>
<td>45.6</td>
<td>50.2</td>
<td>46.3</td>
</tr>
</tbody>
</table>

Siemens QA Test Results: Spec > 30

QA results should be ≈ > 1.5 times spec! (On some systems they should be >2x spec.)
Obtaining Channel Images - GE

1. Enter Patient ID: geservice
2. Setup and save test sequence
3. DOWNLOAD sequence
4. Right Click on Research
5. Display CVs (Control Variables)

6. Set ‘saveinter’ to 1
   Save Intermediate

7. Set ‘nograd’ to 1
   No Gradient Warp correction

8. ACCEPT
9. DOWNLOAD
10. RUN
# Obtaining Channel Images - Siemens

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Go to System tab</td>
</tr>
</tbody>
</table>
| 2.   | Find and select “Save Uncombined Images”  
      (Depends on Software Level) |
| 3.   | Go to Resolution tab |
| 4.   | Go to Filter sub-tab |
| 5.   | Turn off ALL filters. |
| 6.   | On some pre-Aera/Skyra systems there is an additional option under System tab: “Double” or ”Triple” which affect Body Matrix and Head Matrix coils. |

Much easier!
1. Go to "Postproc" tab
2. Select “Save Raw Data”
3. Turn off all filters

4. Go to “Geometry” tab
5. Set “Image Shutter” to ‘no’
6. Run the scan

7. Now comes the hard part! Find the “Delayed Reconstruction” option

8. Select the Exam to reconstruct

9. Select the “Prev scan” to reconstruct.
10. Select “Synergy Selection”

11. Enter the single channel to reconstruct.

12. Go to Scan List

13. Select the scan line

14. Use “Options” to rename it with channel
15. Copy the line for all of the channels to reconstruct. Max is 9!

16. Rename each line so you know the channel.

17. Select Plan for EACH and EVERY line, one at a time!

18. Change the channel #
19. Start Scan

20. After all channels have been reconstructed, download images to your laptop.

21. Calculate the composite image as the square root of the sum of the squares of all of the channels!

22. You’re done!
   (Wasn’t that fun?)