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Determination of Signal-to-Noise Ratio and Image Uniformity for Single-Channel Non-Volume Coils in Diagnostic MR Imaging

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CONTENTS

Figures

Preamble

This is one of a series of test standards developed by the medical diagnostic imaging industry for the measurement of performance parameters governing image quality of magnetic resonance (MR) imaging systems. These test standards are intended for the use of equipment manufacturers, prospective purchasers, and users alike.

Manufacturers are permitted to use these standards for the determination of system performance specifications. This standardization of performance specifications is of benefit to the prospective equipment purchaser, and the parameters supplied with each NEMA measurement serve as a guide to those factors that can influence the measurement. These standards can also serve as reference procedures for acceptance testing and periodic quality assurance.

It must be recognized, however, that not all test standards lend themselves to measurement at the installation site. Some test standards require instrumentation better suited to factory measurements, while others require the facilities of an instrumentation laboratory to assure stable test conditions necessary for reliable measurements.

The NEMA test procedures are carried out using the normal clinical operating mode of the system. For example, standard calibration procedures, standard clinical sequences, and standard reconstruction processes shall be used. No modifications to alter test results shall be used unless otherwise specified in these standards.

The NEMA Magnetic Resonance Section has identified a set of key magnetic resonance image quality parameters. This standards publication describes the measurement of two parameters for special purpose single-channel non-volume coils; signal-to-noise ratio (SNR) and uniformity.

Equivalence

It is intended and expected that manufacturers or others who claim compliance with these NEMA standard test procedures for the determination of image quality parameters shall have carried out the tests in accordance with the procedures specified in the published standards.

In those cases where it is impossible or impractical to follow the literal prescription of a NEMA test procedure, a complete description of any deviation from the published procedure must be included with any measurement claimed equivalent to the NEMA standard. The validity or equivalence of the modified procedure will be determined by the reader.

Uncertainty of the Measurements

The measurement uncertainty of each image quality parameter determined using this standards publication is to be reported, together with the value of the parameter. Justification for the claimed uncertainty limits shall also be provided by a listing and discussion of sources and magnitudes of error.

Foreword

This standards publication is classified as a NEMA standard unless otherwise noted. It is intended for use by manufacturers of MRI systems and accessory equipment and by MRI end users.

It describes a method for evaluating single-channel non-volume special purpose radio-frequency (RF) coils for use with magnetic resonance (MR) imaging (MRI) systems. These coils are used to receive signal from a limited region of interest. These include linear or quadrature combined surface coils, flexible coils, pairs of coils such as Helmholtz coils, or coils that partially surround a specific tissue such as the calf or other extremity. Both receive-only and transmit-receive coils are included. The system head and body coils, and single-channel volume specialty coils, are excluded (see MS 1 and MS 3). Also excluded are coils that require multiple receiver channels for operation (array coils, see MS 9). However, if analyzing one channel of an array coil, this standard may be used. Independent of intended use, for the purpose of this standard, the coils being analyzed will be called "surface coils." These coils achieve good signal-to-noise performance because of their increased filling factor; in most cases, however, these coils have a non-uniform signal distribution.

The purpose of this procedure is to provide a standard means for measuring and reporting the signal-to-noise ratio (SNR) and uniformity of signal intensity in images acquired with surface coils. These quantities are helpful in evaluating coil performance and effectiveness. Evaluations are performed on phantom images generated using standard clinical scan protocols.

This standards publication has been developed by the Magnetic Resonance Section of the Medical Imaging Technology Alliance, a division of the National Electrical Manufacturers Association. User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

Vice President, Technical Services Department
Medical Imaging Technology Alliance/National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

Section approval of the standard does not necessarily imply that all section members voted for its approval or participated in its development. At the time it was approved, the section was composed of the following members:

Computer Imaging Reference Systems—Norfolk, VA
GE Healthcare, Inc.—Milwaukee, WI
Hitachi Medical Systems America, Inc.—Twinsburg, OH
Invivo—Gainesville, FL
Medipattern Corporation—Toronto, ON, Canada
Philips Healthcare—Andover, MA
Siemens Medical Solutions, Inc.—Malvern, PA
Toshiba America Medical Systems—Tustin, CA

Rationale

Typically, coils are constructed to optimize the signal-to-noise ratio (SNR) of images from a restricted imaging region of interest (IROI). A simple example would be a single loop surface coil placed close to the IROI as compared to a cylindrical volume coil that may surround the IROI, thereby encompassing a volume. This measurement procedure defines the volume near the surface coil, which produces a useful signal, and estimates the SNR about a reference point within that volume. Methods to characterize image uniformity for such coils are also provided.

The increased signal-to-noise performance of some of these coils is accompanied by a loss of image uniformity. While a high level of image uniformity is generally a desirable goal for volume coils, the reduction of signal from areas outside the IROI can be exploited using surface coils to reduce motion artifacts or to reduce image wrap-around artifacts caused by under-sampling when the field of view is small. Therefore, it is appropriate to map the sensitive volume of a surface coil, since a simple figure of merit for uniformity can be misleading.

The SNR is a sensitive, but rather non-specific, measure of MR system performance. It can be used to assess the effect of alterations in the MR system (excluding the coil), or it can be used to compare the performance of two coils. Given that the sensitivity of many surface coils is spatially dependent, the assessment of the effect of alterations in the MR system can be achieved by measuring the SNR about a fixed reference point relative to the coil position. Since different coils are designed for different coil-to-tissue distances, it is not possible to fix a single reference position that is appropriate for all coil designs. The reference position selected shall approximate the position of the IROI for which the coil is used or intended. This standard allows flexibility in the choice of reference position; however, this flexibility may prevent direct comparison of different coil designs.

The loading of surface coils may vary substantially from application to application and even from exam to exam depending on coil placement. Because of these variations, a generic coil loading scheme is not included in this standard. Since both loaded and unloaded SNR's are sensitive to changes in the remainder of the MR system (although the loaded SNR may be more representative of typical conditions), one condition shall be selected for this measurement procedure.

Phantoms are objects that contain MR signal producing material and are generally used for SNR and uniformity testing of RF coils. It is recognized that as field strength (frequency of operation) increases, wavelength effects become more significant, particularly above 64MHz. Therefore, this standard allows for the use of water-based or non-aqueous (e.g. oil-based) phantom fluids, without regard to field strength or frequency of operation, and emphasizes instead that the phantom fluid that is actually used be adequately specified for purposes of reproducibility.

The use of geometric distortion correction algorithms and image uniformity correction algorithms is becoming increasingly common, and in some situations necessary. Both types of corrections will alter image uniformity results reported in this standard. While it was the original intent of this standard to characterize the coil without these corrections, it is also the intent of the standard to test the coil under typical clinical conditions. .

Multiple measurement procedures are offered for SNR and image uniformity as per the methods of MS1 and MS3. The preferred methods are referred to as primary methods. The primary measurement procedures may require access to MRI system software functions normally available only to the MRI system manufacturer. Other possible methods are referred to as alternate methods. The alternate measurement procedures employ user accessible software functions.

Scope

This standards publication defines test methods for measuring the signal-to-noise ratio and image uniformity of MR images produced using special purpose single-channel non-volume coils or a single channel of an array coil.. ("surface coils"). These methods are applicable to both receive-only and transmit-receive RF coils. This document does not address the use of general head and body coils, special purpose single-channel volume coils (see MS 1 and MS 3), or analysis of data from coils that require multiple receiver channels for operation (array coils, see MS 9).

Section 1
DEFINITIONS

1.1 COIL-RELATED DEFINITIONS

1.1.1 Sensitive Volume

The sensitive volume is that volume within which the MR signal of a uniform phantom is greater than or equal to 10 percent of the MR signal measured at the reference position.

1.1.2 Sensitive Area

The sensitive area is the intersection of an image slice with the sensitive volume and also contains the reference position.

1.1.3 Imaging Region of Interest (IROI)

A general term used to define a volume in which a surface coil may produce useful imaging results. The IROI relates to the intended use or application of the coil and should be considered when selecting a reference position and geometry and location of phantom.

1.1.4 Reference Position

The reference position is a user selected point within the sensitive volume of the coil. Typically this is chosen based on the distance of the imaging region of interest from the coil.

1.2 ANALYSIS-RELATED DEFINITIONS

1.2.1 Characterization Volume

The characterization volume is a regular geometric volume selected for measurement. The characterization volume shall contain as much of the sensitive volume as is practical, as well as the reference position.

1.2.2 Characterization Area

The characterization area is the intersection of an image slice with the characterization volume and also contains the reference position.

1.2.3 Measurement Region of Interest (MROI)

A regular geometric area of the image centered at the reference position. These measurement regions shall be either a 7x7 square array of pixels, or a circular region containing at least 49 pixels. For measurement regions containing noise information, the array shall be an 11x11 array of pixels, or some other, more complex rectilinear, continuous region, containing at least 121 pixels.

1.2.4 Measurement Subregion of Interest (SROI)

In an alternate image uniformity measurement method described in section 2.7, multiple subregions of interest (SROIs) are defined for measuring image/signal values, each being a 7x7 square array of pixels.

1.3 PHANTOM-RELATED DEFINITIONS

1.3.1 Signal-Producing Volume (Phantom)

For purposes of this standard, SNR and image uniformity measurements are performed using a homogeneous test phantom. The geometry of this test phantom defines the MR signal-producing volume.

The phantom geometry defines the characterization volume unless it is larger than the sensitive volume of the coil. It is preferable but not mandatory that the signal-producing volume covers or substantially covers the entire sensitive volume of the coil.

1.4 IMAGE-RELATED DEFINITIONS

1.4.1 Image Artifact

An image artifact is an image anomaly, excluding random noise, that is not representative of the structure or chemistry of the object being scanned, or that is derived from the structure or chemistry of the object being scanned but which appears in the image at a location other than expected.

1.4.2 Image Uniformity/Non-uniformity

The signal pixel intensity variation within an image that is repeatable from scan to scan.

An absence of image non-uniformity (N) is defined as N=0% and perfect image uniformity (U) is defined as U=100%. The relationship is: U = 100 - N.

1.4.3 Baseline Pixel Offset Value

The baseline pixel offset value is the pixel value for a particular MR system that represents a noise-free signal level of zero.

1.4.4 Image Signal

The mean pixel value within the MROI (minus the baseline pixel offset, if any) in the original, unsubtracted image is the image signal.

1.4.5 Image Noise

The random variations in pixel intensity in the MROI are called image noise.

1.4.6 Image Signal-to-Noise Ratio

The image signal-to-noise ratio is a single number obtained by dividing the image signal by the image noise.

Section 2
METHODS OF MEASUREMENT

2.1 TEST HARDWARE

2.1.1 MR Characteristics of the Signal-Producing Volume (Phantom)

The following are the desired MR characteristics of the signal-producing volume:

T_1 < 1200 milliseconds (at operating field strength)
T_2 > 50 milliseconds (at operating field strength)

The phantom geometry, material, additives, and any special preparation procedures, shall be specified with the results to allow reproducibility.

It shall be permitted to use non-aqueous (e.g. oil-based) or water-based phantoms. Take care to select materials and additives that do not cause undue wavelength ("dielectric resonance") effects at the MR frequency of operation.

If the T_1 and T_2 properties are different from those stated above, the differences shall be noted with the results.

2.1.2 RF Coil Loading Characteristics

A loading scheme is not included in this standard. Since, generally, both loaded and unloaded SNR and uniformity are sensitive to changes in the remainder of the MR system, either shall be permitted in this measurement procedure (see Rationale).

2.1.3 RF Coil and Positioning Device

The RF coil to be tested shall be used with its normal positioning device, and placed in a position that is representative of normal use. It is recognized that one may choose to test coils at the magnet center even if typically used in an offset position. In any event, the coil position in the magnet shall be reported with the results.

2.2 SELECTION OF MEASUREMENT GEOMETRY

In this section, we describe the requirements for the selection of characterization area(s), based on coil geometry. Given that a particular surface coil may be used for different target anatomies, select one such anatomical use for the coil under test. Place an appropriate signal-producing volume (phantom) on the coil. Make the phantom large enough to cover a significant portion of the sensitive volume, and inclusive of a reference position. Where appropriate, the use of a phantom positioning device or holder that is both phantom and coil specific is recommended to allow repeatable placement of the phantom on the coil. Position the coil and phantom combination at either magnet isocenter or the target offset location selected for this particular coil use condition, if such an offset condition ("typical use condition") is selected for measurement.

2.2.1 Selection of the Reference Position , Characterization Volume and Area

Select a reference position. Considering the geometry of the test phantom, select a characterization area or areas that contain the reference position. Locate the phantom in relation to the coil to allow scanning of the characterization area.

2.2.2 Measurement Region-of-Interest (MROI)

The MROI was previously defined in general (7x7 pixel area centered on the reference position). The mean signal-intensity value of the MROI shall be used as the numerator of the SNR. In addition, a preliminary calculation of the SNR within the MROI shall be used to select pixels for the noise calculation.

2.2.3 Noise Evaluation Area

When using image subtraction methods for SNR evaluation, image noise shall be evaluated within a regular closed geometric area comprising the 49 pixels of the MROI plus at least 72 additional pixels. The shape of the noise evaluation area shall be chosen to ensure that at least 121 pixels have relatively high signal-intensity values within the signal image (see Section 2.4, item g for criterion). The simplest noise evaluation area would be an 11 x 11 pixel square area that is centered on the reference position (see Figure 2-1), although certain coils may require a more complex geometry to ensure that all of the pixels meet the signal-intensity value requirement. The use of filters and distortion correction algorithms may alter the noise statistics in various ways (see Figure 2-2).

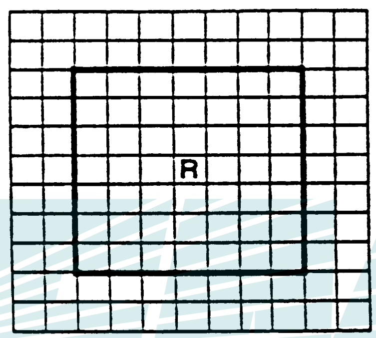

Figure 2-1
SIMPLEST GEOMETRY OF NOISE EVALUATION AREA

NOTE — Figure 2-1 shows the simplest geometry for the noise evaluation area. An 11 x 11 pixel square is centered on the reference position R. The outlined 7 x 7 pixel square is the MROI. The noise evaluation area contains 121 pixels, the minimum required by this standard, so every pixel must meet the intensity value requirement of Section 2.4, item g.

Authorized Engineering Information

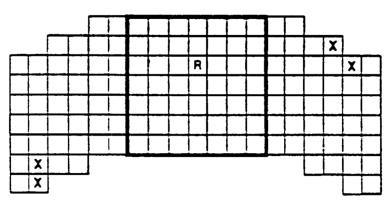

Figure 2-2
COMPLEX GEOMETRY OF NOISE EVALUATION AREA

NOTE — The geometry of Figure 2-1 is not always suited to every coil type. Figure 2-2 shows a more complex geometry. The noise evaluation area consists of 133 pixels. In this example, some of the pixels do not meet the intensity value requirement of Section 2.4, item g, (the pixels that do not meet the requirement are identified with 'X') and are not included in the standard deviation (noise) calculation. Since more than 121 pixels do meet the requirement, a valid data set for noise evaluation is provided.

Authorized Engineering Information

2.2.4 Slice Positions

Uniformity measurements are performed in two orthogonal planes. SNR is evaluated in one of these planes. Both planes must pass through the reference position, since the purpose of the measurement is to demonstrate the falloff of signal away from the coil structure. This also facilitates measurement of the distance between the coil and the reference position on the images. For most surface coils, the slice planes shall be orthogonal to the plane of the coil and shall include the central axis of the coil (see Figure 2-3). For elliptical or rectangular surface coils, one plane shall include the major axis of the ellipse or rectangle, and the other shall include the minor axis of the ellipse or rectangle. Where the surface coil is not planar, e.g. shaped/flex surface coil, the two planes shall be placed relative to the surface coil in a manner similar to what is shown in Figure 2-3 (generally along axes of symmetry of the coil). In all cases, the slice positions shall be indicated on the drawing that accompanies the measurement results (see Section 3).

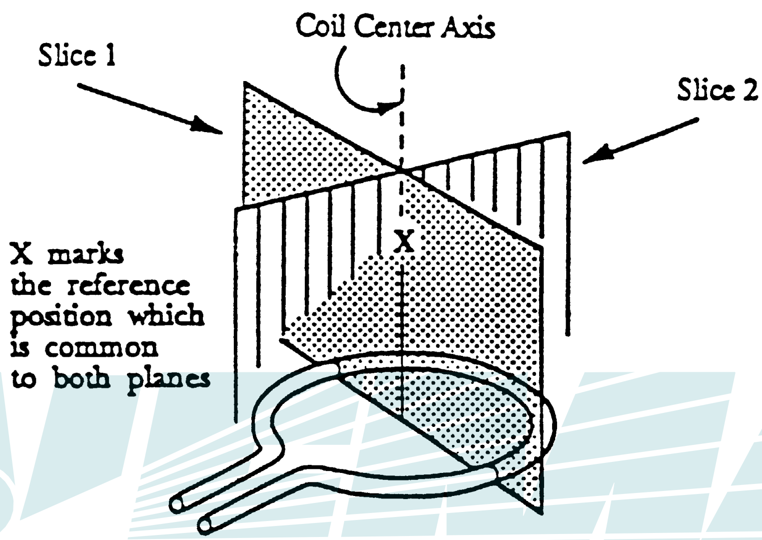

Figure 2-3
SLICE POSITIONS FOR A SURFACE COIL

2.3 SCAN CONDITIONS

A single spin-echo imaging technique is recommended in this standard for measuring SNR and uniformity. This is not a mandatory requirement. Sufficient sequence information is to be provided with the test results so that the imaging test conditions can be reproduced. In addition, the following scan conditions shall be used to acquire data:

Room and phantom temperature shall be 22 ± 4 °C, or as otherwise specified by the manufacturer of the MR system (indicate actual temperature with test results). Preferably the actual room temperature is measured and reported with the results.

TR ≥ 3 x T_1 of phantom filler material in the signal-producing volume.

TE within clinically selectable range.

Spin echo pulse sequence (first echo). Specify pulse sequence type in case spin echo is not used.

Slice thickness ≤ 10 mm.

Matrix size within clinically selectable range (record voxel size in results).

The field of view for each image must encompass the characterization area for the selected image plane.

Two sets of images will be produced with a typical clinical scan sequence:

1) without geometric distortion correction or RF uniformity correction algorithms or image processing filters, to the extent controllable by the user,
2) with geometric distortion correction and RF uniformity correction algorithms, but no image processing filters, to the extent controllable by the user.

The images to be analyzed shall be substantially free of image artifacts, other than image uniformity due to spatial variations in the sensitivity of the surface coil.

2.4 PRIMARY MEASUREMENT PROCEDURE FOR SNR

Surface coil SNR is determined by sequentially executing the following procedure. This method is the same as that defined in MS1, Method 1. The images recorded during this procedure can additionally be evaluated for uniformity.

a. Position the signal-producing volume relative to the surface coil as prescribed in Sections 2.1.3, 2.2.1 and 2.2.4. One of the two slice positions described in Section 2.2.4 is selected for the SNR measurement. In the reporting of results note which slice is used for SNR.
b. Perform the standard clinical pre-scan calibration procedure as recommended by the system manufacturer.
c. Execute two scans sequentially of the same slice, with less than 5 minutes elapsed time from the end of the first scan to the beginning of the second (image 1 and image 2). No system adjustment or calibration shall be performed between the scans.
d. Determine the mean pixel value within the MROI (as defined in Section 2.2.2) on image 1. The resulting number (minus any baseline pixel offset value) shall be called the image signal (S).
e. Calculate a pixel-by-pixel signed difference image (hereafter referred to as image 3) as follows:

$$[\text{image 3}] = [\text{image 1}] - [\text{image 2}]$$

NOTE—The image subtraction process must avoid overflow and underflow errors that could result from the generation of any pixel values that are outside the range of maximum and minimum pixel values allowed on the particular scanning system.

f. Calculate the standard deviation within the MROI of the subtracted image (image 3). This value is divided by the square root of two to give the preliminary image noise estimate (P).
g. Examine those pixels in image 1 which fall within the noise evaluation area (as defined in Section 2.2.3) and reject any pixels that have signal-intensity values less than 5 x P (adjusting for any baseline pixel offset). (See NOTE below.) At least 121 pixels must remain in image 3 that are artifact-free and contain a uniform/random noise distribution. Otherwise, an imaging protocol having greater SNR must be chosen, or a larger noise evaluation area must be defined. The coordinates of the pixels within the MROI of image 1 that have signal-intensity values greater than or equal to 5 x P are the valid noise pixel positions.

NOTE — In absolute value images, the noise in regions with significant signal has a Gaussian distribution, while the noise in non-signal-containing areas has a Rayleigh distribution. In order to make this procedure valid for both real and absolute value images, noise shall be evaluated only in those areas containing significant signal. This is accomplished by making a preliminary image noise estimate (see Section 2.4 item f) based on the MROI and then identifying in the original, unsubtracted image those pixels within the noise evaluation area that have intensities of at least five times the preliminary image noise estimate.

h. Determine the standard deviation (SD) of the pixels in image 3 that have the coordinates of the valid noise pixels. Noise statistics may be affected significantly by filtering methods.
i. Calculate the SNR as follows:

$$SNR = \frac{S\sqrt{2}}{SD}$$

2.5 ALTERNATE SINGLE-IMAGE MEASUREMENT PROCEDURE FOR SNR

The SNR of a surface coil can alternatively be determined by sequentially executing the following procedure. This method is the same as that defined in MS1, Method 4. The image recorded during this procedure can additionally be evaluated for uniformity.

a. Position the signal-producing volume relative to the surface coil as prescribed in Sections 2.1.3, 2.2.1 and 2.2.4. One of the two slice positions described in Section 2.2.4 is selected for the SNR measurement. In the reporting of results note which slice is used for SNR.
b. Select a field of view (FOV) such that the image contains a signal- and artifact-free area with random noise distribution with at least 121 pixels as defined in Section 2.2.3. The FOV in this case may need to be larger than in 2.4 to enable sufficient signal-free area for noise measurment. The signal MROI is as defined in Section 2.2.2.
c. Perform the standard clinical pre-scan calibration procedure as recommended by the system manufacturer.
d. Execute one scan and determine the mean signal pixel value (S) in the signal MROI.
e. Adjust the window level of the image so that potential image artifacts (ghosting, noise lines, etc.), if any, become visible. Measure the standard deviation (SD) of the noise contained in a signal- and artifact-free area of the image. The position of the noise evaluation area relative to the reference position shall be noted. Noise statistics may be affected significantly by filtering methods.
f. Calculate the SNR as follows:

$$SNR = 0.655\frac{S}{SD}$$

NOTE —The factor 0.655 arises because, in absolute value images, the noise in regions with significant signals has a Gaussian distribution, while the noise in non-signal-containing areas has a Rayleigh distribution.

Additional alternate methods are allowed for measuring SNR. The methods described in MS 1, Method 2 and Method 3, as applicable, may be used. The user should note the method used with the results.

2.6 PRIMARY MEASUREMENT PROCEDURE FOR IMAGE UNIFORMITY

Surface coil image uniformity is determined by sequentially executing the following procedure. Note: an image from the SNR measurement may be used for one of the two uniformity measurements. Steps a through d shall be repeated for each of the two scan planes (slice positions).

a. Position the signal-producing volume relative to the surface coil as prescribed in Sections 2.1.3, 2.2.1 and 2.2.4.
b. Perform the standard clinical pre-scan calibration procedure as recommended by the system manufacturer.
c. Acquire the image.
d. Image uniformity shall be determined by manipulation of the resulting images to produce a contour map. A single gray level shall be assigned to all pixels in the signal-containing area of the image having intensity values (I) such that:

$$S \times (1 - F) < I \le S \times (1 + F)$$

Where:

S is the mean pixel value within the MROI (as defined in Section 2.2.2) minus any baseline pixel offset value.
F is a fraction with a fixed value of 0.1 that specifies the width of a histogram bin.
I is the intensity value that has been corrected for baseline pixel offset, if any.

Pixels in the signal-containing area of the image having intensities:

$$S \times (1 + F) < I \le S \times (1 + 2 \times F)$$

are assigned the next brighter gray level.

This process is continued, with each gray level including pixels for which I is:

$$S \times (1 + n \times F) < I \le S \times (1 + (n+1) \times F),\ n = 1, 2, 3 \ldots$$

until all pixels brighter than S have been assigned a gray level. Pixels in the highest intensity bin are assigned to white.

A similar procedure is applied to pixels with intensities less than S x (1 - F). The gray level bins in this case are defined by:

$$S \times (1 - (n+1) \times F) < I \le S \times (1 - n \times F),\ n = 1, 2, 3 \ldots$$

until all pixels darker than S have been assigned a gray level. Pixels in the lowest intensity bin are assigned to black.

The resulting images shall be labeled to indicate physical dimensions.

2.7 ALTERNATE MEASUREMENT PROCEDURE FOR IMAGE UNIFORMITY

The image uniformity of a surface coil can alternatively be determined by sequentially executing the following procedure. Note: an image from the SNR measurement may be used for one of the two uniformity measurements. Steps a through d shall be repeated for each of the two scan planes (slice positions).

a. Position the signal-producing volume relative to the surface coil as prescribed in Sections 2.1.3, 2.2.1 and 2.2.4.
b. Perform the standard clinical pre-scan calibration procedure as recommended by the system manufacturer.
c. Acquire the image.
d. Define a rectangular or other regular geometric area that covers at least 75% of the characterization area, denoted as the ROI, and entirely containing 17 SROIs that have 7 x 7 pixel square areas (see Figure 2-4). Determine the mean signal intensities S1 through S17 at the locations defined as follows:

   S1: Central SROI.
   S2: Top of the ROI, vertically displaced from S1.
   S3: Half distance between S2 and S1, displaced vertically.

S4: Bottom of the ROI, vertically displaced from S1.
S5: Half distance between S4 and S1, displaced vertically.
S6: Far left side of the ROI, horizontally displaced from S1.
S7: Half distance between S6 and S1, displaced horizontally.
S8: Far right side of the ROI, horizontally displaced from S1.
S9: Half distance between S8 and S1, displaced horizontally.
S10: Far top left corner of the ROI, displaced diagonally.
S11: Half distance between S10 and S1, displaced diagonally.
S12: Far bottom left corner of the ROI, displaced diagonally from S1.
S13: Half distance between S12 and S1, displaced diagonally.
S14: Far top right corner of the ROI, displaced diagonally.
S15: Half distance between S14 and S1, displaced diagonally.
S16: Far bottom right corner of the ROI, displaced diagonally from S1.
S17: Half distance between S16 and S1, displaced diagonally.

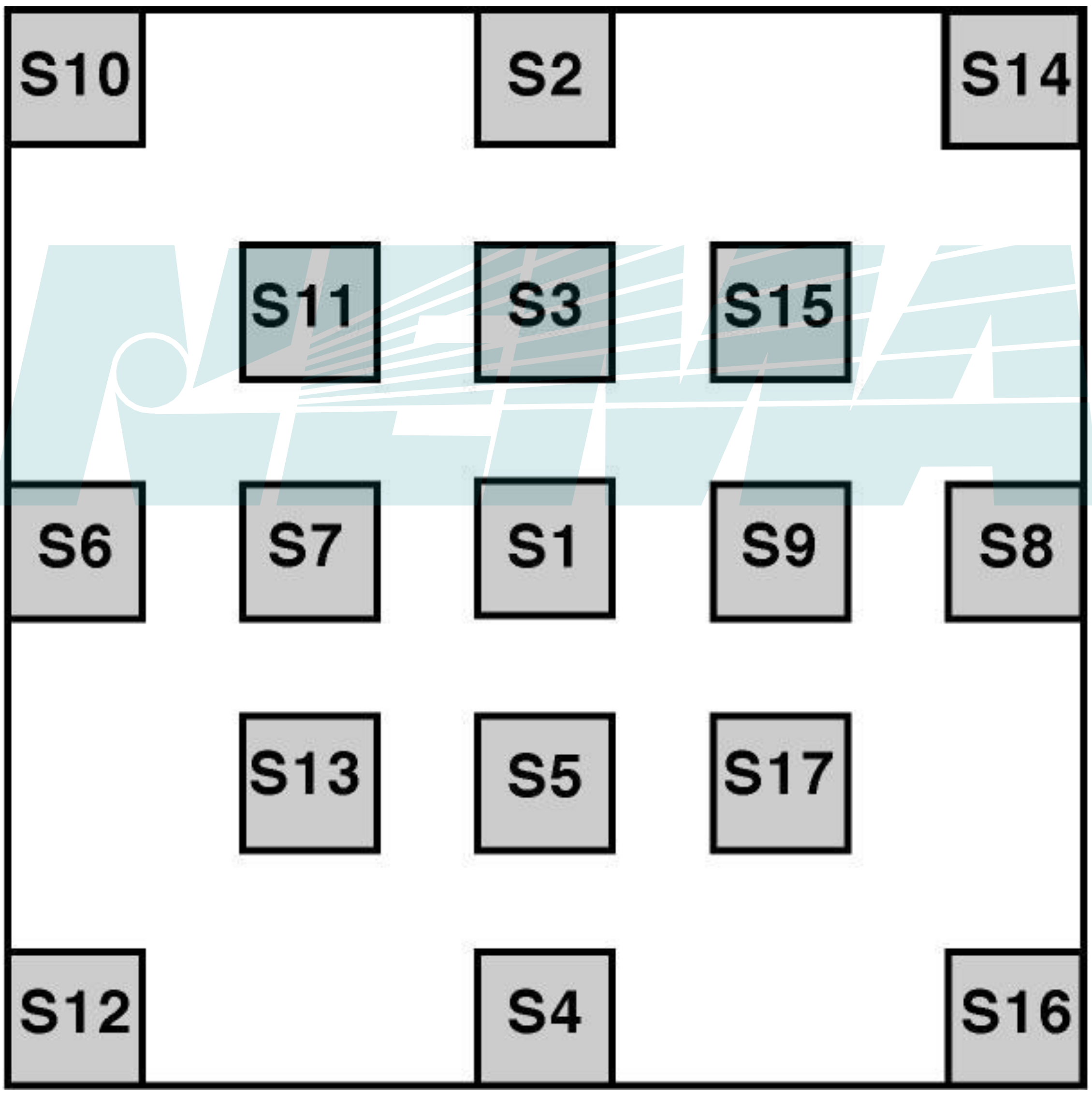

Figure 2-4
ROI FOR IMAGE UNIFORMITY MEASUREMENT

Record the position of the ROI relative to the reference position and the size of the ROI.

e. Calculate the nonuniformities N1 through N17 using:

$$N_n = \frac{|S_n - S_1|}{|S_n + S_1|}$$

where n = 1,2,3,…17.

Additional alternate methods are allowed for measuring image non-uniformity. The methods described in MS 3, as applicable, may be used. The user should note the method used with the results along with any information required for reproducibility.

Section 3
REPORTING OF RESULTS

3.1 REPORTING OF SNR

3.1.1 Geometric Information

A dimensioned drawing (or drawings) showing the following geometric information must accompany the statement of the image SNR:

a. Main magnetic field (B_0) direction and strength
b. Position of the surface coil with respect to the gradient/system isocenter
c. Position of the phantom and characterization volume with respect to the coil structure
d. Size and shape of characterization volume
e. Position of the slice within the characterization volume and resulting characterization area
f. Position of the MROI within the characterization volume (this also defines the reference position)
g. Size and shape of the noise evaluation area and its position relative to the MROI

3.1.2 Data Acquisition Parameters

The following data acquisition parameters must accompany the statement of the image SNR:

Parameter	Dimension
Phantom related parameters	
Phantom filler T_1	milliseconds
Phantom filler T_2	milliseconds
Phantom filler specific conductance (or phantom filler chemical composition)	siemens per meter (or composition)
Phantom dimensions	millimeters
Acquisition related Parameters	
Pulse sequence name/type	….
Pixel bandwidth	hertz per pixel
Voxel dimensions	millimeters
Field of view	centimeters
Slice thickness	millimeters
Sequence repetition time (TR)	milliseconds
Echo delay time (TE)	milliseconds
Number of signals averaged (NSA)	….
Data acquisition matrix size	….
Receive/Transmit coil(s) used	….
Scanner related parameters and scan conditions	
Software version	…
Statement of geometric distortion correction algorithm	…
Statement of RF receive coil correction algorithm	…
Type of signal filters used (time and/or image domain)	…
Scan room temperature	ºC
Phantom temperature	ºC

If a single spin-echo imaging technique is not used then sufficient sequence information is to be provided with the test report that the imaging test conditions can be reproduced.

A description of the coil loading, if used, shall be provided. If it was not possible to turn off all user-selectable filters (see Section 2.3), the filter that was used shall be noted. If gradient distortion/warp correction methods are used this shall be noted in the results. If RF non-uniformity correction is used this shall be noted in the results.

In addition, any other parameters required to ensure repeatability shall be reported.

3.1.3 SNR Results

The SNR value computed in Section 2.4, item i or Section 2.5, item f shall be provided. The SNR results shall also be reported with and without gradient distortion/warp correction and RF uniformity correction (if it is possible to turn these corrections off).

If an alternate method from MS 1 was used, this shall be specified with the result.

3.2 REPORTING OF UNIFORMITY

Convert any non-uniformity measurements to uniformity measurements per definition 1.4.2.

3.2.1 Geometric and Phantom Information

The parameters listed in Section 3.1.1 must accompany the image uniformity results.

3.2.2 Data Acquisition Parameters

The parameters listed in Section 3.1.2 must accompany the image uniformity results.

3.2.3 Uniformity Results

For the primary measurement procedure, the contour map described in Section 2.6, item d shall be provided. This contour map shall be annotated to show the reference position and the dimension scale.

If the alternate measurement procedure described in Section 2.7 is used, a table of the results described in Section 2.7, item e shall be provided.

If an alternate method from MS 3 was used, this shall be specified with the result. The uniformity results shall also be reported without gradient distortion/warp correction and RF uniformity correction (if it is possible to turn these corrections off).

3.3 UNCERTAINTY OF MEASUREMENTS

The measurement uncertainty of the image quality parameters determined is to be reported, together with the value of the parameter. Justification for the claimed uncertainty limits shall also be provided by a listing and discussion of sources and magnitudes of error.

Annex A
CHANGES TO STANDARD

CHANGES TO MS 6-1999 RESULTING IN MS 6-2008

A.1.1 Summary

The definitions section has been clarified to better identify the regions where measurements are made and their relationships to the phantom and the coil. Specifically, it is broken up into four sections, one to define coil related definitions, one for analysis related definitions, the third for phantom related definitions and the fourth for image related definitions.

A.1.2 Changes to introduction

- "Notice and Disclaimer" section added and expanded.
- Rationale section expanded and clarified.
- Scope section clarified to distinguish this standard from MS1, MS3 and MS9.

A.1.3 Section 1

- Definitions organized according to subject matter: coils, analysis, phantoms and images.
- Definitions and their interrelatedness have been clarified.

A.1.4 Section 2

- Image related definitions removed and placed into Section 1.
- Introduction added to 'Selection of Measurement Geometry'.
- Included statements that additional methods from MS1 and MS3 for SNR and uniformity characterization are allowed as applicable.
- Minor editorial corrections and clarifications made.

A.1.5 Section 3

- Rationalized the reporting requirements for SNR. Structured the required information into two sections: Geometric Information and Data Acquisition Parameters, followed by reporting of the SNR results. These are then carried over to the uniformity section, as referenced sections from the SNR section, followed by reporting of uniformity results.

A.1.6 Annex A

Annex A added to highlight changes between versions of this standard.

CHANGES TO MS 6-2008 RESULTING IN MS 6-2013

- Now permit the analysis of one channel of a multi-channel

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