NEMA Standards Publication

NEMA MS 6-2008 (R2014, R2020)

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

National Electrical Manufacturers Association

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

Published by

National Electrical Manufacturers Association
1300 North 17th Street, Suite 900
Rosslyn, VA 22209

www.nema.org

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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 (vendors) 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 nonuniform 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:

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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, VAGE Healthcare, Inc. – Milwaukee, WI
Hitachi Medical Systems America, Inc. – Twinsburg, OH.
Invivo – Gainesville, FL.
Medipattern Corporation – Toronto, Ontario, 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)