

NEMA MS 2-2008 (R2014,R2020)

Standard for
Determination of
Two-Dimensional
Geometric Distortion
in Diagnostic Magnetic
Resonance Images



NEMA Standards Publication MS 2-2008 (R2014,R2020)

*Determination of Two-Dimensional Geometric Distortion
in Diagnostic Magnetic Resonance Images*



Published by:

National Electrical Manufacturers Association

1300 North 17th Street, Suite 900
Rosslyn, VA 22209

www.nema.org

© 2021 National Electrical Manufacturers Association. All rights, including translation into other languages, reserved under the Universal Copyright Convention, the Berne Convention for the Protection of Literary and Artistic Works, and the International and Pan American Copyright Conventions.

NOTICE AND DISCLAIMER

The information in this publication was considered technically sound by the consensus of persons engaged in the development and approval of the document at the time it was developed. Consensus does not necessarily mean that there is unanimous agreement among every person participating in the development of this document.

The National Electrical Manufacturers Association (NEMA) Standards and guideline publications, of which the document contained herein is one, are developed through a voluntary consensus Standards development process. This process brings together volunteers and/or seeks out the views of persons who have an interest in the topic covered by this publication. While NEMA administers the process and establishes rules to promote fairness in the development of consensus, it does not write the document and it does not independently test, evaluate, or verify the accuracy or completeness of any information or the soundness of any judgments contained in its Standards and guideline publications.

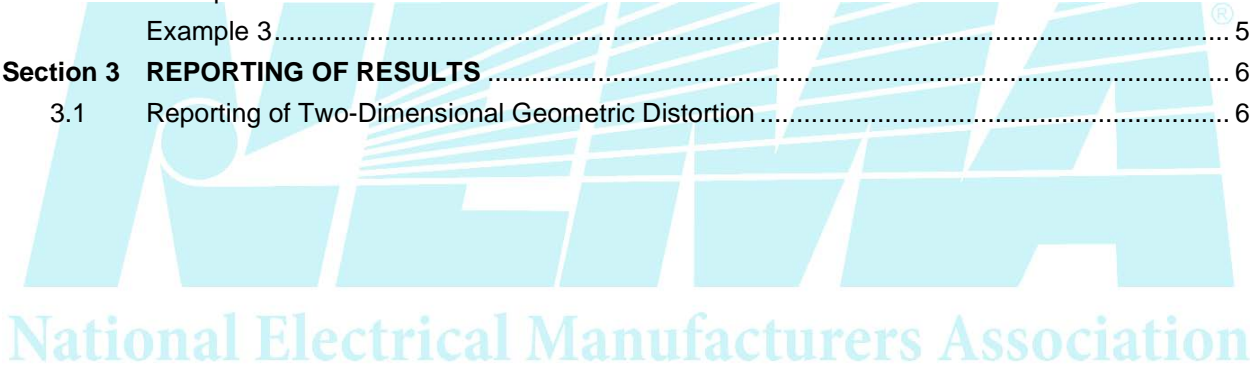
NEMA disclaims liability for any personal injury, property, or other damages of any nature whatsoever, whether special, indirect, consequential, or compensatory, directly or indirectly resulting from the publication, use of, application, or reliance on this document. NEMA disclaims and makes no guaranty or warranty, expressed or implied, as to the accuracy or completeness of any information published herein, and disclaims and makes no warranty that the information in this document will fulfill any of your particular purposes or needs. NEMA does not undertake to guarantee the performance of any individual manufacturer or seller's products or services by virtue of this Standard or guide.

In publishing and making this document available, NEMA is not undertaking to render professional or other services for or on behalf of any person or entity, nor is NEMA undertaking to perform any duty owed by any person or entity to someone else. Anyone using this document should rely on his or her own independent judgment or, as appropriate, seek the advice of a competent professional in determining the exercise of reasonable care in any given circumstances. Information and other Standards on the topic covered by this publication may be available from other sources, which the user may wish to consult for additional views or information not covered by this publication.

NEMA has no power, nor does it undertake to police or enforce compliance with the contents of this document. NEMA does not certify, test, or inspect products, designs, or installations for safety or health purposes. Any certification or other statement of compliance with any health or safety-related information in this document shall not be attributable to NEMA and is solely the responsibility of the certifier or maker of the statement.

Contents

	Page
Preamble	ii
Foreword.....	iii
Rationale.....	iv
Scope.....	v
History.....	v
Section 1 DEFINITIONS	1
1.1 Specification Volume	1
1.2 Specification Area.....	1
Section 2 METHODS OF MEASUREMENT	2
2.1 Phantom Design	2
2.2 Scan Conditions	2
2.3 Measurement Procedure	2
Example 1.....	3
Example 2.....	4
Example 3.....	5
Section 3 REPORTING OF RESULTS	6
3.1 Reporting of Two-Dimensional Geometric Distortion	6



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 (MRI) 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 one of these parameters.

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 the 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 MRI system manufacturers, manufacturers of accessory equipment (including special purpose gradient coils), and MRI end users.

The purpose of this procedure is to provide a Standard means for measuring and reporting two-dimensional geometric distortion in an MRI system. Two-dimensional geometric distortion is defined here as the maximum percent difference between measured distances in an image and the actual corresponding phantom dimensions. Radial measurements, i.e., between points spanning the geometric center of the test object, are used to characterize the geometric distortion. Measurements will be evenly spaced with an angular separation less than or equal to 45° in order to sample sufficiently the angular variation of geometric distortion.

This Standards publication has been developed by the Magnetic Resonance Section 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
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
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
Confirma, Inc.—Bellevue, WA
GE Healthcare, Inc.—Milwaukee, WI
Hitachi Medical Systems America, Inc.—Twinsburg, OH
Invivo Corporation, Gainesville, FL
Medipattern Corporation—Toronto, ON
Philips Healthcare —Andover, MA
Siemens Medical Solutions, Inc.—Malvern, PA

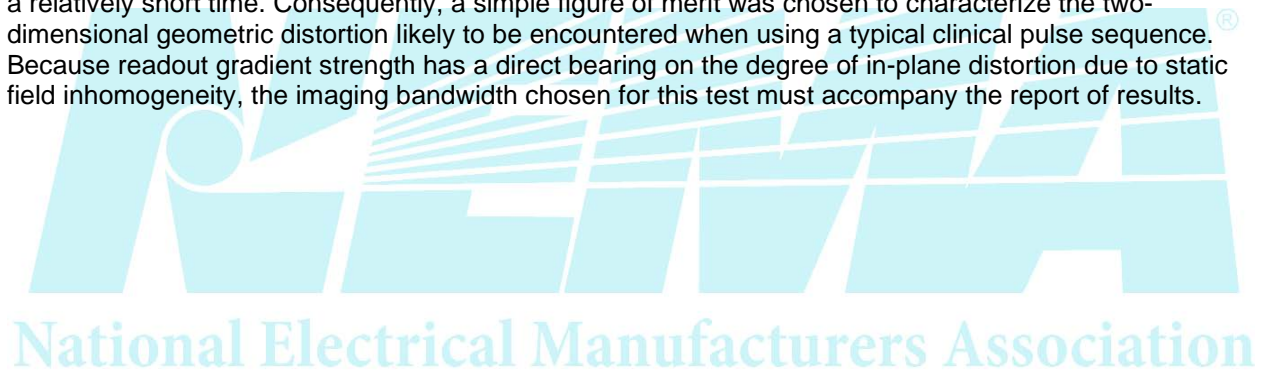
Toshiba America Medical Systems—Tustin, CA

Rationale

One of the essential attributes of an MRI scanner is its ability to produce a two-dimensional map, or image, of the nuclear magnetic resonance (NMR) signal as a function of position within the object under study. It is natural, therefore, to seek to determine the extent to which the spatial relationships in the image correspond to the actual spatial relationships in the object.

Geometric distortion in a two-dimensional MRI image can be caused by a number of factors, including, but not limited to, inhomogeneity of the main magnetic field (B_0), gradient field nonlinearity, gradient amplitude miscalibration, eddy current effects, and magnetic susceptibility effects. A number of specialized techniques have been developed to identify particular sources of geometric distortion, to quantify and in some cases to correct for the distortions introduced. For example, magnetic field mapping and shimming techniques are essential tools employed by the MR system manufacturer to reduce B_0 inhomogeneities to a minimum. Nevertheless, geometric distortion correction algorithms are sometimes employed in the reconstruction of an image in order to further reduce distortions. Such algorithms are permitted under this Standard, so long as they are an integral step in the reconstruction of an image.

Two-dimensional geometric distortion in an MR image can be characterized in a number of different ways. The choice of a measurement and reporting method was guided by a desire for computational simplicity and ease of implementation on all MR systems. It was also intended that the results could be obtained in a relatively short time. Consequently, a simple figure of merit was chosen to characterize the two-dimensional geometric distortion likely to be encountered when using a typical clinical pulse sequence. Because readout gradient strength has a direct bearing on the degree of in-plane distortion due to static field inhomogeneity, the imaging bandwidth chosen for this test must accompany the report of results.



Scope

This Standards publication describes a method for determining the maximum percent difference between measured distances in an image and actual corresponding phantom dimensions. The procedure described evaluates geometric distortion in three orthogonal planes passing through the center of the specification volume.

This procedure does not address the question of the absolute positional accuracy of the image of the test object in the frame of reference of the magnet. Only the relative separation of selected points on the test object is considered. This procedure does not address the measurement of slice flatness or the accuracy of slice positioning.

History

MS 2-2003 differs from its predecessor MS 2-1989 in the following ways:

1. A Rationale has been added.
2. The Scope of the Standard has been more precisely delineated.
3. The scan conditions explicitly stipulate that the spatial resolution be the same in the frequency- and phase-encoding directions.
4. Geometric distortion correction algorithms are permitted so long as they are an integral step in the reconstruction of an image. These were not considered in the predecessor Standard.
5. Numerous editorial changes have been made to improve readability.

MS 2-2008 differs from its predecessor MS 2-2003 in the following way:
The definition for "Specification Volume" has been revised.

National Electrical Manufacturers Association