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Determination of Two-dimensional Geometric Distortion in Diagnostic Magnetic Resonance Images

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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NEMA Standards Publication MS 2-1989 (R1996)

Determination of Two Dimensional Geometric Distortion in Diagnostic Magnetic Resonance Images

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Preamble

This is one of a series of test standards developed by the medical diagnostic industry for the measurement of performance parameters governing the image quality of Magnetic Resonance 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 subdivision has identified a set of key magnetic resonance image quality parameters. This Standard 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 to be equivalent to the NEMA standard. The validity or equivalence of the modified procedure will be determined by each reader.

Uncertainty of the Measurements

The measurement uncertainty of the image quality parameter determined using this standard 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.

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Foreword

This NEMA Standards Publication, MS 2-1989 was approved as NEMA Standard on September 6, 1989. It describes a method for the evaluation of two-dimensional geometric distortion in an MR imaging system. This test has been designed so that the results can be obtained in a relatively short period of time. This procedure has also been designed to accommodate all MR imaging systems.

Two-dimensional geometric distortion is defined in this standard as the maximum percent difference between measured distances in an image and the actual corresponding phantom dimensions.

Radial measurements are used to characterize the geometric distortion. Measurements will be evenly spaced with an angular separation less than or equal to 45° to avoid simple angular dependence of distortion.

User needs have been considered throughout the development of this publication. Proposed or recommended revisions should be submitted to:

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Scope

This NEMA Standard describes a method for the determination of the maximum percent difference between measured distances in an image and actual corresponding phantom dimensions. The procedure described evaluates geometric distortion over the entire specification volume. This procedure does not address the measurement of slice flatness.

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DETERMINATION OF TWO-DIMENSIONAL GEOMETRIC DISTORTION IN DIAGNOSTIC MAGNETIC RESONANCE IMAGING

Section 1
DEFINITIONS

1.1 SPECIFICATION VOLUME

The specification is the imaging volume within which a manufacturer guarantees image performance specifications. Images or portions of images outside this volume will not necessarily meet performance specifications, but can still be useful for diagnostic purposes and require subjective judgement on the part of the diagnosing physician. For head scans, the specification volume must enclose, as a minimum, a ten centimeter diameter spherical volume (dsv) centered in the RF head coil, and similarly for body scans it must enclose, as a minimum, a twenty centimeter dsv centered in the RF body coil.

1.2 SPECIFICATION AREA

The specification area is the intersection of the specification volume and the image plane.

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Section 2
METHODS OF MEASUREMENT

2.1 SCAN CONDITIONS

Image data shall be acquired using a typical clinical scan sequence and reconstruction process, which has not been altered in any fashion to affect the results. In addition, the following scan conditions shall be used to acquire the data:

1. Phantom centered in the RF receive coil;
2. Room and phantom temperature of 22±4°C;
3. TE (echo time) and TR (repetition time) within the clinically selectable range;
4. Single slice acquisition centered at isocenter;
5. Field of view of the scan selected so that both pixel dimensions shall be ≤1 percent of the maximum dimension of the specification area in order to minimize errors due to large pixel size;
6. Spin echo pulse sequence (first echo); and,
7. Slice thickness ≤10 mm.

2.2 RF COIL LOADING CHARACTERISTICS

RF coil loading will not affect the distortion measurement. Therefore the design of the phantom need not consider this parameter.

2.3 PHANTOM DESIGN

The phantom shall be designed such that geometric distortion can be measured over the perimeter of the entire specification area.

The phantom shall consist of a series of rings, holes, pins, or other defined edges that follow the perimeter of the specification area.

The phantom shall be at least twice as thick as the slice thickness used in the measurement, to minimize the influence of slice curvature.

2.4 MEASUREMENT PROCEDURE

This procedure is intended to evaluate geometric distortion over the entire specification volume.

2.4.1 The phantom shall be positioned and the data acquired in accordance with the conditions as specified in 2.1.

2.4.2 Separate scans shall be performed in the three orthogonal planes centered at the isocenter (axial, sagittal, coronal).

2.4.3 The distance between diametrically opposed pairs of points shall be measured. The phantom shall have at least four pairs of evenly distributed reference points which lie on the perimeter of the specification area. The lines connecting these points pass through the phantom center. The angles between pairs of adjacent connecting lines shall be less than or equal to 45°. Refer to Examples 1, 2, and 3.

2.5 RESULTS

Geometric distortion for each of the orthogonal scans shall be reported as the maximum absolute difference (in percent) between any of the measured distances and the actual corresponding phantom dimensions, i.e.,

$$\text{geometric distortion} = \text{MAX}\left\{100\times|L_m-L_a|/L_a\right\}$$

where:

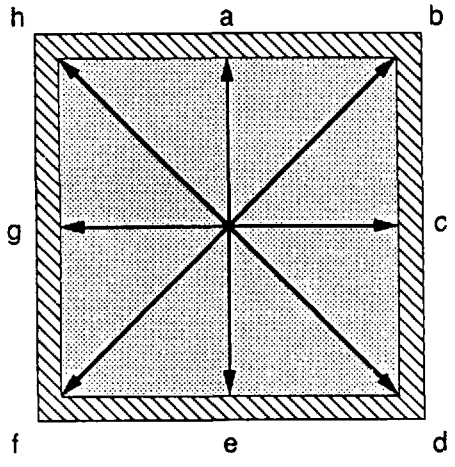
L_m = distance measured on image, and
L_a = actual phantom dimension

(see table in Example 1).

Important: Statement or quotation of geometric distortion must be accompanied by the following parameters:

1. Scan conditions of 2.1 and other relevant scan parameters needed to ensure repeatability;
2. Specification volume (description and dimension);
3. Phantom description;
4. Field of view;
5. Data acquistion matrix size;
6. Pixel bandwidth (hertz per pixel);
7. Read-out gradient direction; and,
8. Scan plane orientation.

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The gray area is both the specification area and the liquid in the phantom.

The striped area is the plastic wall of the phantom.

Evaluation

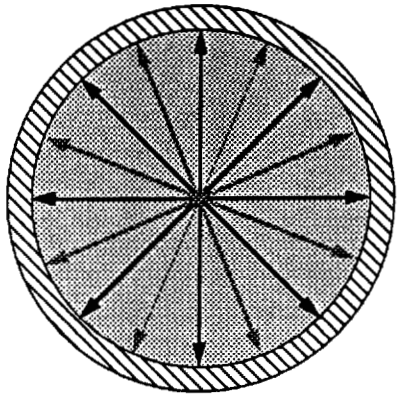
Line segment	Measured on image (cm) L_m	Actual phantom dimension (cm) L_a	Absolute difference (cm) $\lvert L_m - L_a \rvert$	Percent difference $\frac{\lvert L_m - L_a \rvert}{L_a} \times 100$
ae	19.7	19.9	0.2	1.0
bf	28.5	28.2	0.3	1.1*
cg	20.1	20.0	0.1	0.5
dh	28.1	28.2	0.1	0.4

* maximum to be reported

Example 1

The specification volume is cubic, and the specification area is square. The signal-producing region of the phantom matches the specification area exactly. The four distances shown are measured from the image and are compared to the actual phantom dimensions.

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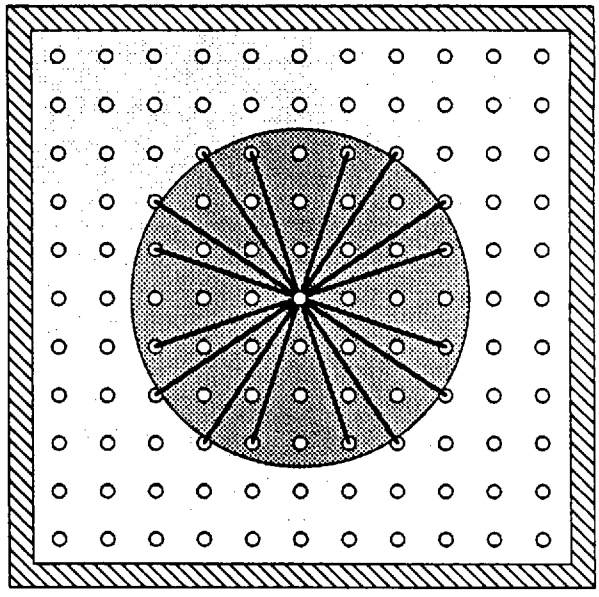
The gray area is both the specification area and the liquid in the phantom.

The striped area is the plastic wall of the phantom.

Example 2

The specification volume is spherical, and the specification area is a disk. The signal-producing region of the phantom matches the specification area exactly. The four distances indicated with black arrows are measured from the image and are compared to the actual phantom diameter. Additional measurements (shown by gray arrows) are suggested. A central pin in the phantom is useful, but not essential, for ensuring that each of the measurements represents a diameter.

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The darker gray area is the specification area.

The striped area is the plastic wall of the phantom.

The lighter gray area is within the phantom, but not in the specification area.

The small circles mark the positions of pins in the phantom.

Example 3

The specification volume is spherical, and the specification area is a disk. The signal-producing region of the phantom extends beyond the specification area. After selecting pins which approximate the periphery of the specification area, diameters are constructed and measured on the image; these are compared to the corresponding distances measured from the phantom.

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National Electrical Manufacturers Association standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist purchasers in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.
(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.
(Standardization Policies and Procedures, p.8)

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National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product, process, or procedure commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 7 & 16)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.
(Standardization Policies and Procedures, pp. 7 & 16)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.
(Standardization Policies and Procedures, pp. 7 & 16)

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Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

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