

IEEE Std 1302-1998

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IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz

IEEE Electromagnetic Compatibility Society

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IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz

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**Standards Committee
of the
IEEE Electromagnetic Compatibility Society**

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Abstract: Information to assist users of gaskets in evaluating gasket measurement techniques to determine which reveal the properties critical to the intended application, to highlight limitations and sources of error of the competing measurement techniques, and to provide a basis for comparing the techniques is provided. Emphasis is placed on those measurement techniques that have been adopted through incorporation into standards, both commercial and military, or that have been used extensively.

Keywords: aperture transmission, electromagnetic interference (EMI) gaskets, electromagnetic shielding, measurement techniques, reverberation chamber, stirred mode, transfer impedance

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Introduction

(This introduction is not part of IEEE Std 1302-1998, IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz.)

An electromagnetic interference (EMI) gasket is a conductive material that is used to improve the electrical bonding between metallic parts of an electronic chassis, equipment enclosure, or electromagnetic shield. A wide variety of materials and techniques are used to produce EMI gaskets. The effectiveness of gaskets in the closing of seams and joints is dependent upon the properties of the gasket and the method of installation. Several techniques are available to measure the electromagnetic properties of EMI gaskets. Unfortunately, measurement results are often inconsistent between techniques.

This document provides guidance on the use of recognized techniques for the electromagnetic performance characterization of EMI gaskets. It does not recommend one technique over another. It is recognized that some or all of the “alternative” techniques may, at some time in the future, become widely accepted and practiced. At that time, this guide will be revised to reflect their adoption. It is also recognized that efforts are currently underway to revise the measurement techniques currently covered in this guide. These revisions will be included in future updates of this guide.

The theory of gasket behavior given in this guide is highly simplified, and is intended to illustrate primary principles only. For a greater understanding of the electromagnetic interactions that occur in a gasketed joint, the reader is advised to consult the many excellent mathematical treatments in books and papers available through the IEEE and other technical publishers.

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IEEE Guide for the Electromagnetic Characterization of Conductive Gaskets in the Frequency Range of DC to 18 GHz

1. Overview

1.1 Background

The ideal electromagnetic shield is an infinitely conductive enclosure with no apertures or penetrations of any kind. The functional requirements and practicalities of design and construction, however, prevent this ideal from being realized. Penetrations for power, signals, and ventilation must be provided. Access apertures for calibrations, controls, and adjustments must exist. The different pieces of chassis and enclosure must be joined for the final product.

Electromagnetic energy exits or enters the shield at apertures, along conductive penetrations, and through imperfect seams. To restrict this coupling of energy to levels that are sufficiently low to comply with regulations and to permit interference-free operation, these unwanted coupling paths must be closed. Filters are used on the penetrations; screens and covers may be used over the apertures. Seams and joints, however, require special attention. For shielding, metal-flow processes such as welding, brazing, and soldering are the preferred methods for making joints and seams. Many situations arise, however, in which these techniques cannot be used, and in which direct metal-to-metal contact does not provide an adequate electromagnetic seal. In these cases, an electromagnetic interference (EMI) gasket must be installed in the joint.

EMI gaskets are conductive materials that are designed to conform to joint surfaces and to provide a low-impedance path. EMI gaskets are made from a wide variety of materials, such as beryllium copper, galvanized steel, stainless steel, electroplated steel, aluminum, and conductively loaded polymers. Conductor types include spring fingers, spiraled bands, perforated sheets, knitted wire mesh, conductive fabric, reinforced foil, and oriented wires. Materials added to polymeric binders to achieve conductivity include copper, silver, carbon, aluminum, and nickel as flakes, powders, wires, and coated spheres. The shapes available include sheets, strips, washers, tubes, and customized geometries.

The term “EMI gasket” is consistent with the generic industrial definition of a gasket. The electromagnetic fields that are being shielded impinge upon the conductive materials of the enclosure. The incident field induces currents in the enclosure walls. Seams represent discontinuities in shield current paths, with result-

ing voltage differentials across the seams. The purpose of the EMI gasket is to reduce the voltage differential across the seam because the strength of the field emanating from the seam is directly proportional to this voltage.

Depending upon function and application, electronic equipment must operate in an extremely wide range, in both intensity and frequency, of electromagnetic environments. The environments can vary from that of the home to that of the battlefield. Since there is no “one size/type fits all” gasket, the challenge that faces equipment designers is that of choosing the most cost-effective gasket for their particular application.

An essential parameter in this selection process is the degree to which the gasket prevents the electromagnetic energy that impinges on one side of the metal joint containing the gasket from coupling through the joint to the other side (i.e., the gasket’s electromagnetic sealing capability). Many factors determine the electromagnetic seal provided by an EMI gasket, including

- a) The gasket material
- b) The gasket construction
- c) The geometry of the joint
- d) The condition of the contact surfaces
- e) The method of fastening
- f) The closure pressure
- g) The nature of the impinging field

The ideal EMI gasket measurement technique would reveal the full range of effects caused by mounting surface variations, aging, and fasteners, and would provide results that indicate the behavior that is expected from the gasket as installed. Currently, no single measurement technique does this over the frequency range of dc to 18 GHz.

1.2 Scope

This guide provides guidance on the selection of the best technique for measuring EMI gaskets for particular applications, identifies limitations and sources of errors of the commonly accepted techniques for measuring gaskets, and provides a basis for comparing the various accepted techniques. It encompasses measurements of the as-installed behavior of gaskets as well as manufacturing related, quality-control measurements.

1.3 Purpose

The purpose of this guide is to provide information that will allow the user of conductive gaskets to select the best measurement technique for a given application and to correctly interpret the data that is provided by each technique.

2. References

This guide shall be used in conjunction with the following standards. A bibliography is included in Clause 10 for further information.

ANSI/NCSL Z540-1-1994, Calibration—Calibration Laboratories and Measuring and Test Equipment—General Requirements.¹

¹ANSI publications are available from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

ARP 1173-1988 (Reaff 1991), Test Procedure to Measure the RF Shielding Characteristics of EMI Gaskets.²

ARP 1705-1981 (Reaff 1991), Coaxial Test Procedure to Measure the RF Shielding Characteristics of EMI Gasket Materials.

ASTM D4935-89 (1994), Standard Test Method for Measuring the Electromagnetic Shielding Effectiveness of Planar Materials.³

Def Stan 59-103 (17-Sep-93), EMI/EMP Gasket Components.⁴

IEEE Std 100-1996, IEEE Standard Dictionary of Electrical and Electronics Terms.⁵

IEEE Std 299-1997, IEEE Standard for Measuring the Effectiveness of Electromagnetic Shielding Enclosures.

MIL-G-83528B (1993), General Specifications for Gasketing Material, Conductive, Shielding Gasket, Electronic, Elastomer, EMI/RFI.⁶

NCSL RP-12 (4/95), Recommended Practice for Determination and Reporting of Measurement Uncertainties.⁷

3. Definitions, acronyms, and abbreviations

3.1 Definitions

All terms used in this document are in accordance with IEEE Std 100-1996.

3.2 Acronyms and abbreviations

ARP	aerospace recommended practice
dB μ V/m	decibels above a microvolt per meter
dB μ A/m	decibels above a microampere per meter
EME	electromagnetic environments
EMI	electromagnetic interference
MSC	mode-stirred chamber
SAE	Society of Automotive Engineers
SE	shielding effectiveness
TEM	transverse electromagnetic

²Aerospace Recommended Practices are available from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096, USA.

³ASTM publications are available from the American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

⁴Defence Standards may be obtained from the Ministry of Defence, Directorate of Standardization, Kentigern House, 65 Brown Street, Glasgow, Scotland, G2 8EX.

⁵IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

⁶MIL publications are available from Customer Service, Defense Printing Service, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094, USA.

⁷NCSL publications can be obtained from the National Conference of Standards Laboratories, 1800 30th Street, Suite 305B, Boulder, CO 80301-1032, USA.

4. Factors affecting gasket performance

Figure 1 illustrates a typical application in which the EMI gasket is placed underneath the lip of a cover in order to close the gap between it and the base enclosure. Other similar applications are under connector shells, waveguide flanges, filter cans and meter flanges, and in seams. The objective of the gasket is to provide an electrical path across the gap in the shield, such that the impedance of the path through the gasket approaches that of a comparable span of the base shield. The impedance of the gasket is a function of its materials and construction, its geometry, and the interface between the gasket and the shield.

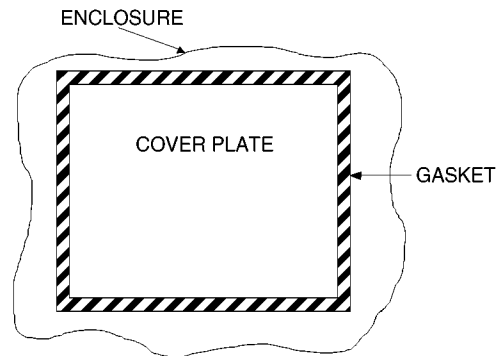


Figure 1—Typical gasket application

All gasket materials have resistive, inductive, and capacitive properties that may exhibit themselves over different portions of the frequency band. Which property determines the gasket's predominant characteristic depends upon the materials and construction of the gasket, as well as the geometry of the joint. Most gaskets can be considered resistive at low frequencies. Those gaskets that are constructed of metal filaments (oriented wires or wire meshes) and fingers or spirals typically appear as an inductance in series with a resistance. Gaskets that are formed from conductively loaded polymers typically appear as a shunt capacitance in parallel with a resistance. These complex impedances determine the effectiveness of the gaskets as frequency increases. Therefore, reliance on volume resistivity data taken at dc or at power frequencies can be very misleading.

All gaskets behave as complex networks of resistors, inductors, and capacitors at frequencies at which their physical dimensions become significant fractions of a wavelength, or the spacings between constituent elements approach or exceed resonant dimensions. Furthermore, the gasketed joint is polarized. This polarization is the consequence of the joint being long and narrow, and of the conductors of the gasket being preferentially aligned with a field component of the incident wave.

The gasketed joint can behave like a section of waveguide that is filled with conductive materials. When this happens, the gasket and aperture will exhibit complex radiation and transmission properties. Coupling through this aperture is likely to be of greater importance to shielding effectiveness than the enclosure itself. Where the gasket does not appear homogeneous, it is not safe to assume that the current through the gasket is uniform or that it is determined by the shield. The characteristics of the incident field must also be considered; the radiation characteristics of the total aperture must be recognized; and the propagation of the coupled wave through the "loaded" aperture must be taken into account.

Shield current encounters both the contact impedance between the gasket and the impedance of the gasket itself. On the contact surfaces, there are often films of metal oxides and sulfides, paints, cleaners, dust, dirt and environmental deposits. Such films will likely be present on gasket surfaces as well.

NOTE—Many surface films are nonconductive. Depending upon the compression-deflection properties of the gasket material, the nature of its conductive elements (e.g., “gritty” particles, oriented wires, knitted wires, etc.), and the closure force applied, certain gaskets will “bite” through such films more effectively than others. This “biting” may or may not be desirable, depending upon the application environment, as it may open a site for corrosion or galvanic action over the life of the equipment. Environmental testing should be considered for every application.

The path for current from the shield to the gasket will be through the ridges and valleys on the mating surface that result from machining or casting imperfections to the contacted portions of the gasket materials. The contact impedance between the gasket and the parent shield can be a significant factor in the overall behavior of the gasket. This contact impedance will have reactive components in addition to resistance. For example, there is usually some capacitive coupling between the contact surface and the conductors in the gasket.

In addition to the impedance of the gasket and the gasket-to-shield interface, the shield current encounters the resistive and inductive elements of the shield itself, and a portion flows around the gasket via the stray capacitance between the two pieces of parent material. Thus, the current path through a gasket is a complex network, as illustrated in Figure 2. As complex as this network appears, it is actually somewhat of a simplification. At very short wavelengths, in particular, the gasketed joint will also behave in roughly the same manner as the braid of a coaxial shield. The openings in the braid permit energy to leak through. Depending upon the specific configuration of the conducting elements of the gasket, these openings can render the gasket practically transparent at particular frequencies or over certain frequency ranges, see Quine, et al. [B20].⁸

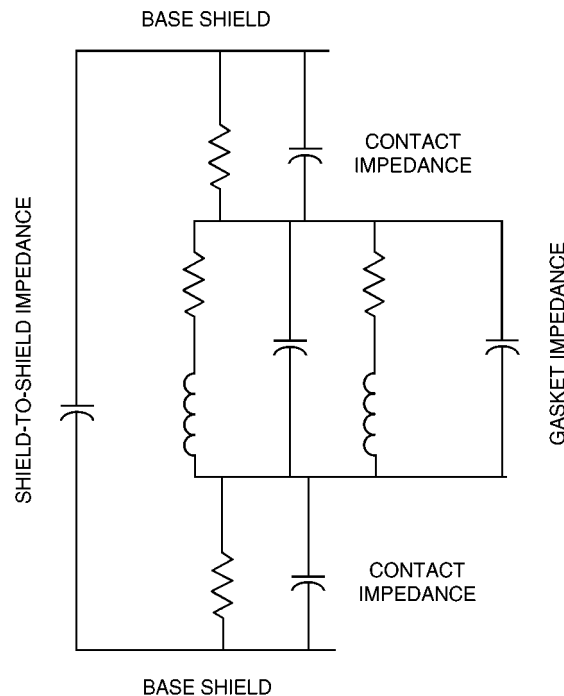


Figure 2—Equivalent circuit of current path through a gasket

Coupling through the gasketed joint will also be influenced by the length of the joint, the number and spacing of fasteners, and the degree to which the gasket material conforms to the joint’s gaps and irregularities

⁸The numbers in brackets preceded by the letter B correspond to those of the bibliography in Clause 10.