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American National Standard Guide for Automated Electromagnetic Interference Measurements

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Accredited Standards Committee on Electromagnetic Compatibility, C63



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American National Standard Guide for Automated Electromagnetic Interference Measurements

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Abstract: U.S. consensus guideline for automation of conducted and radiated EMI compliance measurements is provided in this guide. This document does not include mandatory specifications for automation tools (i.e., application software, automated test equipment, computers and peripherals). Where possible, the guidance provided herein is harmonized with other national and international standards used for similar purposes.

Keywords: conducted emissions, data analysis tools, data handling, exploratory measurements, facility integrity, final measurements, prescans, probability of signal intercept, radiated emissions, sweep times, scan rates

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Introduction

This introduction is not part of ANSI C63.22-2004, Guide for Automated Electromagnetic Interference Measurements.

This introduction provides some background on the rationale used to develop this guide. This information is meant to aid in the understanding and usage of this guide.

This guide describes, in general terms, the use of automatic test equipment and the automation of measurements of electromagnetic emissions. It is intended for the following:

- Individuals or organizations who plan on automating Electromagnetic Interference (EMI) measurements and acquire that application software from a supplier.
- Individuals or organizations who acquire EMI application software from a developer for resale to other individuals or organizations.
- Individuals or organizations who determine the feature set for EMI application software.
- Individuals or organizations who perform automated EMI measurements.
- Software suppliers interested in providing high-quality software to acquirers.

This guide is designed to help individuals or organizations:

- Determine the appropriate feature set of EMI automation software
- Validate the settings of software parameter used to perform measurements
- Determine requirements for test equipment to be used in an automated system
- Determine characteristics of automated test systems for a given test environment

This guide is intended to satisfy the following objectives:

- Promote consistency within organizations in acquiring third-party software from software suppliers
- Provide useful guidelines for the implementation of automated test systems
- Provide useful practices on the determination of necessary software features to automate specific tests
- Provide useful practices on the use of software tools for data acquisition and data analysis purposes
- Assisting individuals and organizations judging the quality and adequacy of supplier software

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Guide for Automated Electromagnetic Interference Measurements

1. Overview

1.1 Scope

The purpose of this document is to provide guidelines for the use of automatic test equipment (ATE) for the measurement of electromagnetic emissions of electronic, electrical, and electro-mechanical equipment. It is intended to be a companion document to ANSI C63.2-1996¹ and ANSI C63.4-2003 for making accurate and repeatable automated emissions measurements from 9 kHz to 1 GHz according to commercial Electromagnetic Interference (EMI) regulations. As such, it addresses automated measurement processes, automatic test equipment, and measurement integrity aspects. Furthermore, the importance of a test plan will be outlined. Although intended for automatic testing, these guidelines also apply to semiautomatic measurements where only parts of a test may be automated.

1.2 Application

The purpose of an automated EMI test system is to increase the efficiency, consistency, and repeatability of both engineering and compliance testing. Successful automated testing requires well-defined automated measurement processes that are appropriate for a specific test goal and ensure measurement integrity.

By automating measurements, the test efficiency can be enhanced and the repeatability of the data collection process improved. Automated measurement processes take care of direct measurement activities such as rotating a turntable, tuning a signal generator or EMI receiver over a frequency range, or changing antenna height and polarization, and thus improve efficiency. Measurement integrity is primarily concerned with the accuracy and repeatability of the results rather than the speed of execution. The integrity of radiated emissions test data, collected on an Open Area Test Site (OATS), is especially difficult to ensure due to the presence of ambient signals and influences of weather conditions on the results. Measurement integrity considerations also address general concerns such as control of EUT operating modes during the test, EUT layout, test system configuration, and data storage and analysis. All these aspects are labor-intensive, prone to errors, and may lead to a lack of repeatability. Automated measurements can overcome many of these issues and improve the quality of test results by ensuring consistency and repeatability. However, a detailed analysis of necessary test procedures and careful definition of measurement algorithms, based on manual measurements, are mandatory for a successful deployment of application software.

¹ Information on references can be found in Clause 2.

When automating EMI measurements, it is essential to ensure data integrity, especially in the case of performing compliance measurements. Measurement instrument settings and all relevant parameters like antenna factors, cable losses, etc., must either be stored along with the test results or the access to these parameters is to be restricted. This will ensure that no changes can be made after the measurement data is taken which would invalidate the test results or make an appropriate interpretation impossible.

ATE can consist of EMI receivers, spectrum analyzers, signal generators, voltmeters, amplifiers, etc., capable of being remotely controlled by computing equipment which can be any kind of controller or computer. The actual instrument control, data acquisition, presentation of measurement results and documentation is usually done by a dedicated application software, specifically designed for automated emissions testing. Each category of ATE will be described separately and no attempt will be made to provide specific programs or software algorithms. It is up to the individual user to ascertain if the used application software correctly processes measurement data to produce accurate results.

System peripherals like plotters and printers will not be discussed in detail and will only be mentioned when they are used at a certain point in the measurement process to record the acquired results or the data which may have been displayed on a spectrum analyzer or EMI receiver.

Almost all of the functions associated with EMI testing may be automated. However, the option of complete or partial manual override is necessary, particularly for engineering tests. Automated emissions testing still requires the EUT to be configured and arranged first for capturing maximum emissions. This includes the determination of the worst-case operating mode and manual cable manipulation.

One of the basic requirements of an ATE system is its user interface and the ease of use provided by it. An operator shall have EMI measurement knowledge, but a high degree of expertise should not be mandatory to run the actual test. However, the test process and selection of the individual steps to be automatically executed needs to be defined by a knowledgeable user. When defining an automated test process, it is recommended that the following factors be taken into account:

- The measurement process should be sufficiently flexible to allow some customizing of the test procedure without jeopardizing the integrity of the test results or consistency of the reporting. This should include quick overview tests with relatively low-frequency resolution and frequency accuracy to capture the emissions profile of an EUT and high resolution and accuracy measurements for the actual determination of the emission frequencies and amplitudes.
- Common repetitive tasks such as maximizing signals, applying correction factors, and generation of test reports should be performed automatically.
- The measurement data should be presented in a manner such that further corrections are not required.
- Results should be stored in a central database or other electronic format for future use and reference.
- Manual interaction with the test system should be possible at all times, or after completion of certain steps, in the automatic measurement procedure.
- The automated test system should be sufficiently flexible and expandable in its frequency range coverage to address future requirements.
- The data format should be compatible with a database program and, if applicable, be acceptable to regulatory authorities.

2. References

The following standards shall be used when implementing this standard. When the standards are superseded by an approved revision, the revision shall apply.

ANSI C63.2-1996, American National Standard for Electromagnetic Noise and Field Strength Instrumentation, 10 Hz to 40 GHz—Specifications.²

ANSI C63.4-2003, American National Standard for Methods of Measurement of Radio-Noise Emissions from Low-Voltage Electrical and Electronic Equipment in the Range of 9 kHz to 40 GHz.

ANSI C63.7-1992, American National Standard Guide for Construction of Open-Area Test Sites for Performing Radiated Emissions Measurements.

ANSI C63.14-1998, American National Standard Dictionary for Technologies of Electromagnetic Compatibility (EMC), Electromagnetic Pulse (EMP), and Electrostatic Discharge (ESD).

CISPR 16-1-1 (2003), Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods—Part 1-1: Radio Disturbance and Immunity Measuring Apparatus.³

CISPR 16-1-2 (2004), Specification for Radio Disturbance and Immunity Measuring Apparatus and Method—Part 1-2: Radio Disturbance and Immunity Measuring Apparatus—Ancillary Equipment—Conducted Disturbances.

ISO/IEC 17025:1999, General Requirements for the Competence of Testing and Calibration Laboratories.⁴

3. Definitions

The following definitions apply specifically to the subject treated in this document. For additional definitions, see ANSI C63.2-1996, ANSI C63.4-2003, ANSI C63.14-1998, CISPR 16-1-1 (2003), and *The Authoritative Dictionary of IEEE Standards, Seventh Edition* [B1].

3.1 alternate test site: An alternate test site used for radiated EMI compliance testing and complying with the requirements in ANSI C63.4-2003.

3.2 conducted emissions test site: A test site used for conducted EMI compliance testing and complying with the requirements in ANSI C63.4-2003. A conducted emissions test site includes LISNs installed according to the requirements documented in ANSI C63.4-2003.

3.3 facility: A complete installation involved in testing, including the actual site, measurement instruments, and support equipment.

3.4 frequency accuracy: Accuracy with which the measuring instrument can determine the frequency of an unknown signal.

² ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

³ CISPR documents are available from the International Electrotechnical Commission, 3, rue de Varembe, Case Postale 131, CH 1211, Genève 20, Switzerland/Suisse (<http://www.iec.ch/>). They are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

⁴ ISO publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembe, CH-1211, Genève 20, Switzerland/ Suisse (<http://www.iso.ch/>). ISO publications are also available in the United States from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (<http://www.ansi.org/>).

3.5 intercept: The detection of an intermittent, impulsive, or slowly varying emission with an EMI receiver.

3.6 list: A tabulation of test data, measurement system settings, limit values or test facility parameters.

3.7 maximum hold function: An EMI receiver or spectrum analyzer function which retains the maximum amplitude value, measured during consecutive sweeps, at each display point in the selected frequency span. The implementation of this function requires a digital display.

3.8 measurement band: A frequency range defined by transducer parameters, spectral characteristics of signals, or software algorithms to achieve a certain measurement goal.

3.9 open area test site: An outdoor measurement location used to perform radiated EMI compliance testing. Requirements for their acceptability and construction are called in ANSI C63.4-2003 and ANSI C63.7-1992 respectively.

3.10 receiver: A measuring instrument that meets the requirements called out in ANSI C63.2-1996 or CISPR 16-1-1 (2003).

3.11 scan rate: The ratio of the selected frequency span and the measuring instrument's sweep time setting.

3.12 scanning receiver: A measuring instrument that complies with the requirements called out in ANSI C63.2-1996 or CISPR 16-1-1 (2003), as applicable, and does not cover a frequency range in discrete frequency steps but continuously tunes across it

3.13 semi-anechoic chamber: A shielded enclosure with a reflecting ground plane and absorber lining on all walls and the ceiling.

3.14 signal identification: The numerical, audible or visual process of identifying two or more signals to be either from different or the same origin.

3.15 site: The environment in which measurements are performed; it includes the ground plane, weather protection, shielding, absorbers, support structures, and surroundings as well as ambient signals.

3.16 sweep time: The time required by the measuring instrument to electronically tune across a selected frequency span.

4. General guidelines for automated measurements

Care should be taken by the automated test system designer in obtaining a thorough understanding of all elements of the measurement process, as well as of the measurement system to be used in the data collection process. The performance of a measurement with a lack of such knowledge may result in the acquisition of erroneous and/or invalid data.

The general automated test system can be divided into four distinct sections. These are 1) the transducer and signal conditioning section, 2) the verification section, 3) the signal measurement section, and 4) the control and data processing section. Though identified as separate entities for clarity in this document (see Figure 1), it should be noted that in many modern EMI test systems, a single equipment item may contain elements of multiple sections as identified here.

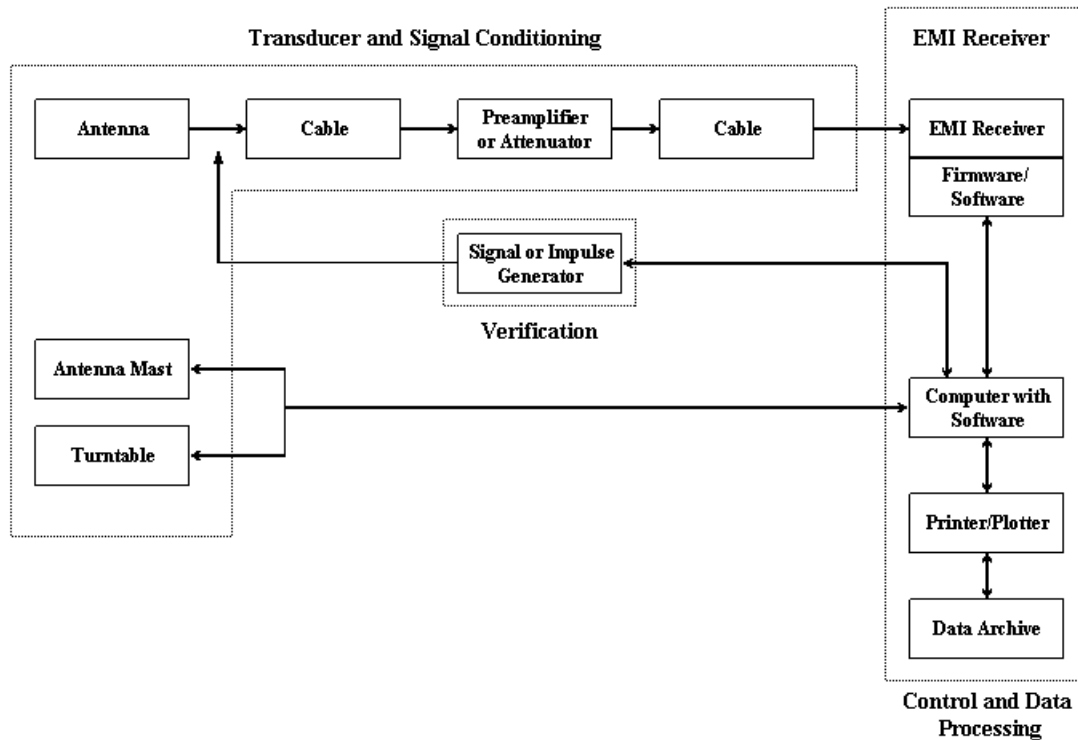


Figure 1—Elements of an automated radiated emission test system

4.1 Transducer and signal conditioning section

The transducer and signal conditioning section of the system consists of all elements that are placed in front of the input connector of the EMI receiver. The function of this section of the system is to intercept the maximum signal levels emitted from the EUT, and transmit this energy to the receiver in a measurable form. These elements can include antennas or *line impedance stabilization networks* (LISNs), cables, the antenna selection RF switch (if multiple antennas are used to cover the appropriate frequency range), and any preamplifiers or attenuators (external to the EMI receiver) necessary to bring the signal levels to be measured to within the dynamic range of the receiver. In addition, included in this section is the antenna tower, and the EUT turntable, which are used to determine the maximum emission levels based on antenna height and polarization as well as EUT orientation relative to the measuring antenna.

4.2 Verification section

The verification section of the emissions measurement system is necessary to ensure that data is collected with a functioning test system and the required tolerances, as per the applicable test specification, are met. The verification section consists of a stable signal source, which should be traceable to national calibration standards (e.g., NIST or other local standards reference organization), the associated cabling, and a dedicated manual or automated procedure. The verification procedure presents a means of quickly demonstrating that most elements of the measurement system, from the transducer output port to the data presentation, perform within previously defined tolerances that are acceptable by the standard to which testing is being performed. It should be noted that this process is not intended to be a detailed true test of the performance characteristics of the receiving system, but merely a means to check the tolerance of the

frequency and amplitude calibration. It does not address many additional and important EMI receiver parameters.

A verification signal can be generated by a stand-alone signal generator, a receiver's tracking generator, or a calibrated impulse generator. Verification, in its most simplified form, is performed by disconnecting the RF coaxial cable from the system's receiving transducer, and connecting it to the verification signal source. The generator's output frequency shall be tuned over the measurement frequency range of interest and its signal amplitude is measured by the EMI receiver. By comparing the current results with previously recorded and verified data, test system malfunctions can be identified quickly and a determination made if the resultant data still meets required tolerances. Once the verification process has been completed, the signal source is disconnected, and the system's receiving transducer reconnected.

4.3 EMI receiver section

The EMI receiver section of the system consists of one or multiple instruments that perform the actual signal measurement. Specifically, the EMI receiver shall have performance characteristics that meet the requirements of ANSI C63.2-1996 and/or CISPR 16 1-1 (2003). In addition, the receiver shall sufficiently meet the actual requirements for testing an EUT to the applicable regulations, especially in regard to the necessary sensitivity and frequency accuracy.

4.4 Control and data processing section

The control and data processing section of the automated measurement system takes many forms. First, any automated control system within the receiver section shall be considered as a part of this section. This includes not only instrument firmware-controlled processor systems, but any software that can be input directly into the receiver's memory, and thereby operates as an onboard control system. Secondly, this area includes external controllers or computers along with their application software. Finally, consideration shall be given to the data storage and output devices like printers or plotters that are a part of the overall system. The quality and resolution of the graphical test data presentation, as well as any tabular information shall meet the requirements of the applied standards and the overall measurement goal (e.g., visual comparison of different sets of data resulting from EUT modifications).

4.5 Precautions for automating EMI measurements

Much of the tedium of making repeated EMI measurements can be removed by automation. Operator errors in reading and recording measurement values are minimized. By using a computer to collect data, though, new forms of errors can be introduced that may have been detected by an operator. In some situations, automated testing can lead to greater measurement uncertainty in the collected data than manual measurements performed by a skilled operator. Fundamentally, there is no difference in the accuracy with which an emission value is measured whether manually or under software control. In both cases, the measurement uncertainty is based on the accuracy specifications of the components used in the test setup. Difficulties may arise, though, when the actual measurement situation is different from the scenarios for which the software was designed.

For example, an EUT emission adjacent in frequency to a high-level ambient signal may not be measured accurately, if the ambient signal is present during the time of the automated test. A knowledgeable tester, however, is more likely to distinguish between the actual interference and ambient signal; therefore, the method for measuring the EUT emission can be adapted as required. However, performing ambient scans prior to the actual emission measurement with the EUT turned off to record ambient signals present on the OATS can sometimes save valuable test time. In this case, the software may be able to warn the operator of the potential presence of ambient signals at certain frequencies by applying appropriate signal identification algorithms.

In a situation where the EUT emission is slowly varying in amplitude, the software may not have been set up for a sufficiently long dwell time at the emission frequency to capture its peak amplitude. By knowing or observing the emission characteristics of the EUT during an overview measurement, the operator will be able to specify the relevant frequency scan parameters during software setup for the final test.

Testing an EUT with a low on-off cycle can cause problems in regard to the probability of intercepting its emissions. If the EMI receiver is tuned to frequencies where no EUT emissions occur during the on-cycle, no emissions are recorded. Therefore, multiple scans may be necessary using a “maximum hold” mode to intercept these kinds of EUT emissions.

Improper data may be recorded during an automated measurement when transient ambient signals are captured, such as arc welding transients, during an OATS test or a brief power line transient from heavy equipment switching. An operator either may not see these signals at all during a manual test or recognize their nature and choose to ignore them as being irrelevant to the test.

The process of finding the EUT and cable configuration that yields the worst case emissions is primarily a manual operation. A scanning receiver providing a graphical display of the emission spectrum and signal max hold capability is of great help for observing the changes in amplitudes as cable and equipment layouts are manipulated. The automated measurement of emissions should begin after the worst case EUT arrangement has been set up.

NOTE—This process can only be done through manual manipulation of the cable configuration.⁵

The measurement of a particular radiated emission includes a maximization process involving the rotation of the EUT, scanning the receive antenna over a height range, and changing antenna polarization. This time-consuming search process can be effectively automated, but it shall be recognized that a variety of search strategies may be used which can lead to different results. In case of previous knowledge of the EUT’s radiation characteristics, a maximization sequence should be chosen that allows the determination of the worst-case amplitude within the search ranges of the antenna mast and the turntable. For instance, if the EUT emits highly directive signals in the horizontal plane, e.g., due to slots in the case, the turntable should be rotated continuously while taking data with the receiver. A turntable rotation in discrete steps, on the other hand, may not allow the detection of the maximum amplitude or may cause the signal to be missed completely in case the chosen angular increments of the turntable positions are too far apart.

One search strategy might be to rotate the turntable 360 degrees while leaving the antenna at a fixed height to find the angle for maximum emission amplitude. Next, the turntable is rotated back over the full range after the antenna polarization has been changed (e.g., from horizontal to vertical). During this process, test data is taken continuously with the receiver and at the end of the second scan the highest amplitudes, based on turntable angle and antenna polarization, are determined. Then, the worst case positions of the antenna and turntable are selected and the antenna is scanned over the required height range to find the position yielding the maximum amplitude. At this point the emission level is either recorded using the appropriate receiver or spectrum analyzer detector after returning to the maximum emission height, or finer search continues with incremental rotation of the turntable and following incremental height search, to find the maximum emission amplitude at the given frequency with greater precision. Again, it is important to have some understanding of the radiation pattern of the EUT in order to set up the software for an optimum search strategy that finds the maximum of the EUT emission in the shortest time. Variability is introduced into the test result when the final measurement is performed on the slope of the signal rather than on its peak.

⁵ Notes in text, tables, and figures are given for information only and do not contain requirements needed to implement this standard.