

IEEE Guide for Near Field Characterization of Unintentional Stochastic Radiators

IEEE Electromagnetic Compatibility Society

Developed by the
Standards Development Committee

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STANDARDS

IEEE Guide for Near Field Characterization of Unintentional Stochastic Radiators

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Standards Development Committee
of the
IEEE Electromagnetic Compatibility Society

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IEEE SA Standards Board

Abstract: This guide provides near-field measurement methods and characterization of stochastic electromagnetic fields emitted from devices. The document includes algorithms for the analysis of the measurements in the frequency range of 30 MHz to 6 GHz.

Keywords: cross-correlation, far field, IEEE 2718™, near field, radiated emissions, stochastic fields, Wigner functions

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Introduction

This introduction is not part of IEEE Std 2718-2023, IEEE Guide for Near Field Characterization of Unintentional Stochastic Radiators.

The growth of Internet-enabled smart infrastructures underpinning virtually every sector of economic and social life requires complex, high performance, and highly integrated electronic systems. The electromagnetic interference (EMI) will increase with the anticipated increase of clock speeds, frequency of operation and circuit density. Immunity levels will also decrease due to lower supply voltages and lower signal power levels. Traditionally, the potential EMI sources were assessed in the frequency domain assuming static emissions. This is not valid for multifunctional devices with many operating modes and wideband digital receivers. New approaches that fully account for time dependence and uncertainty are needed to help ensure the growth and development in the electronics sector is sustainable. This guide provides methods for the characterization of stochastic sources in terms of electromagnetic modelling. Furthermore, this guide provides a guidance for measurement methods based on near field techniques. It is recognized that they are not the unique ones, at some time in the future, they may be revised. These revisions will be included in future updates of this document. The theory for stochastic source characterization given in this guide is summarized to illustrate primary principles and how to get final results. For a greater understanding, the reader is advised to consult the many excellent mathematical treatments papers available through IEEE and other technical publishers and also given, even if in a limited number, in Annex B of this guide.

Acknowledgements

Figure 1 through Figure 5 reprinted with permission from The University of Nottingham, “Simplified Equivalent Modeling of Electromagnetic Emissions from Printed Circuit Boards,” © 2010.

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IEEE Guide for Near Field Characterization of Unintentional Stochastic Radiators

1. Overview

1.1 Scope

This guidance document provides near-field measurement methods and characterization of stochastic electromagnetic fields emitted from devices. The document includes algorithms for the analysis of the measurements in the frequency range of 30 MHz to 6 GHz.

1.2 Purpose

The purpose is to provide guidance for measurement methods and characterization of stochastic electromagnetic fields emitted from devices.

1.3 Word usage

The word *shall* indicates mandatory requirements strictly to be followed in order to conform to the standard and from which no deviation is permitted (*shall equals is required to*).^{6,7}

The word *should* indicates that among several possibilities one is recommended as particularly suitable, without mentioning or excluding others; or that a certain course of action is preferred but not necessarily required (*should equals is recommended that*).

The word *may* is used to indicate a course of action permissible within the limits of the standard (*may equals is permitted to*).

The word *can* is used for statements of possibility and capability, whether material, physical, or causal (*can equals is able to*).

⁶ The use of the word *must* is deprecated and cannot be used when stating mandatory requirements; *must* is used only to describe unavoidable situations.

⁷ The use of *will* is deprecated and cannot be used when stating mandatory requirements; *will* is only used in statements of fact.

2. Normative references

The following referenced documents are indispensable for the application of this document (i.e., they must be understood and used, so each referenced document is cited in text and its relationship to this document is explained). For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies.

IEC TS 61967-3:2014, Integrated circuits—Measurement of electromagnetic emissions—Part 3: Measurement of radiated emissions—Surface scan method.⁸

3. Acronyms and abbreviations

ACCF	cyclic autocorrelation cumulant function
CCCF	cyclic cross correlation function
DUT	device under test
ED	electronic device
EM	electromagnetic
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EUT	equipment under test
FF	far field
FFT	fast Fourier transform
IC	integrated circuit
LISN	line impedance stabilization network
NF	near field
PCB	printed circuit board
2D	two dimensional
3D	three dimensional
4D	four dimensional

⁸ IEC publications are available from the International Electrotechnical Commission (<https://www.iec.ch>) and the American National Standards Institute (<https://www.ansi.org/>).

4. General preliminary procedures

4.1 Overview

This clause provides general and preliminary requirements for the testing environment, the equipment under test (EUT) and the measuring system. Further details and specific requirements are provided in Clause 5 and Clause 7. Figure 1 shows a possible generic set-up for the near field scanning, helping to understand what is reported in the rest of the subclause about environment characteristics. Although the probe holder and the scanning device are not shown in this diagram, they would be present in the actual set-up helping to ensure what is reported in Clause 5.

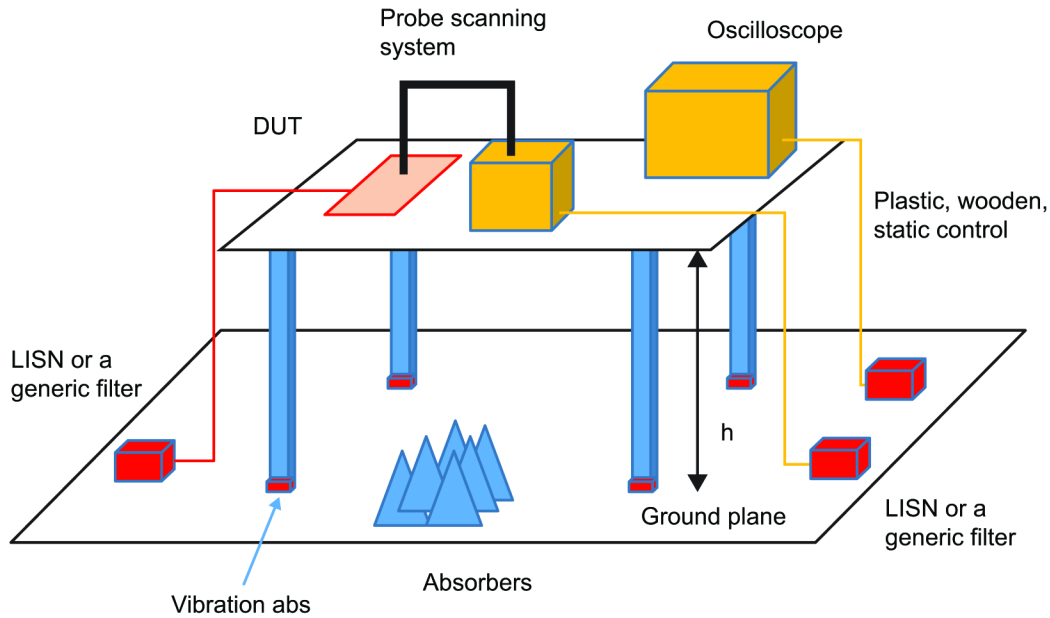


Figure 1—Generic set-up for near field scanning

4.2 Test environment characteristics

The measurement environment in terms of temperature, humidity and vibration can affect the measurement accuracy so should be carefully considered. The environment effects on near field antenna measurement and their mitigation are discussed in IEEE Std 1720™-2012 [B7] and are applicable for stochastic near field measurements.⁹

In particular, temperature variations can cause thermal expansion in cables and probe positioning supports.

The ambient air temperature of the test site shall be within the range of 10 °C to 40 °C (50 °F to 104 °F), unless the EUT requirements specify testing over a different temperature range.

Humidity levels shall be in the range of 10% to 90% relative humidity unless the EUT operating requirements call for a different level. Plastic supports and table are better with respect to wooden ones because they reduce humidity absorption. The ambient temperature and humidity values shall be recorded and included in the test report if critical to the test results.

⁹ The numbers in brackets correspond to those of the bibliography in Annex B.

Vibrations can have an effect on mechanical subsystem positioning accuracies and the stability of probe scanning system. If necessary, vibration absorbers can be positioned under the test table.

Electromagnetic noise can affect measurement results. When the EUT is switched off the measurement values shall be at least 6 dB below those recorded with the EUT active. To reduce electromagnetic radiated noise shielded or anechoic chambers can be used as suggested in Clause 7. Conducted electromagnetic noise can reach the EUT through the power supply cables. Line impedance stabilization networks (LISN) or other power line filters shall be inserted as depicted in Figure 1 to reduce the effect of conducted disturbances.

4.3 EUT conditions

An adequate warm-up time shall be considered to help guarantee the EUT temperature stabilizes before the testing proceeds. Information shall be recovered from the EUT manufacturer, and the warm-up time shall be recorded in the final test report.

If the EUT is fed by a power line network, the voltage stability is important for the measurement results. Typically, a +10/–5% of fluctuations are acceptable unless the EUT functioning requirement are different, see EUT operating manual for this.

In case of battery operated EUT, the voltage reduction of the battery during the test should not affect the emission level. In any case, record the initial and the final battery level in the test report.

The EUT positioning on the test table should respect the manufacturer prescription and typical real life operating conditions. The presence of reflecting objects around the EUT can cause emissions variations. A minimum distance should be respected to reduce probe reading variations. This separation distance shall be recorded by photographs in the test report.

4.4 Scanning system and related instrumentation

An adequate warm-up time shall be considered to help guarantee the EUT temperature stabilizes before the testing proceeds. Information shall be recovered from the EUT manufacturer, and the warm-up time shall be recorded in the final test report.

Accurately follow manufacturer indications for power supply voltage stability and quality required for measurement instrumentation and probe positioning system.

Electromagnetic interference can affect the operation of instruments. Instrumentation should have electromagnetic compatibility (EMC) certification for the country where they operate.

5. Measurement Instrumentation

5.1 Two probe scanner

The measurement of stochastic fields in a transverse plane requires the measurement of the correlation of the fields across the plane. This can be achieved by scanning with two identical moving probes that scan across the surface required. An alternative is to use an array of probes that can simultaneously scan the whole surface area. The scanning resolution may depend on the probe spatial resolution and sensitivity and

the receiver dynamic range. To date, only a two-probe scanner has been fully tested and this is described in this subclause.

For the measurement of the field correlation, use can be made of the symmetry of the correlation matrix.

For scan area of M samples in the x -direction and N samples in the y -direction, only $(M \times N) \times \frac{(M \times N - 1)}{2}$

samples are needed to provide $2M \times N$ autocorrelation values and $2(M \times N)(M \times N - 1)$ cross-correlation samples (see Russer and Braun [B13] and Russer et al. [B15]).

An example scanning pattern for the coordination of the movement of the two probes is shown in Figure 2.

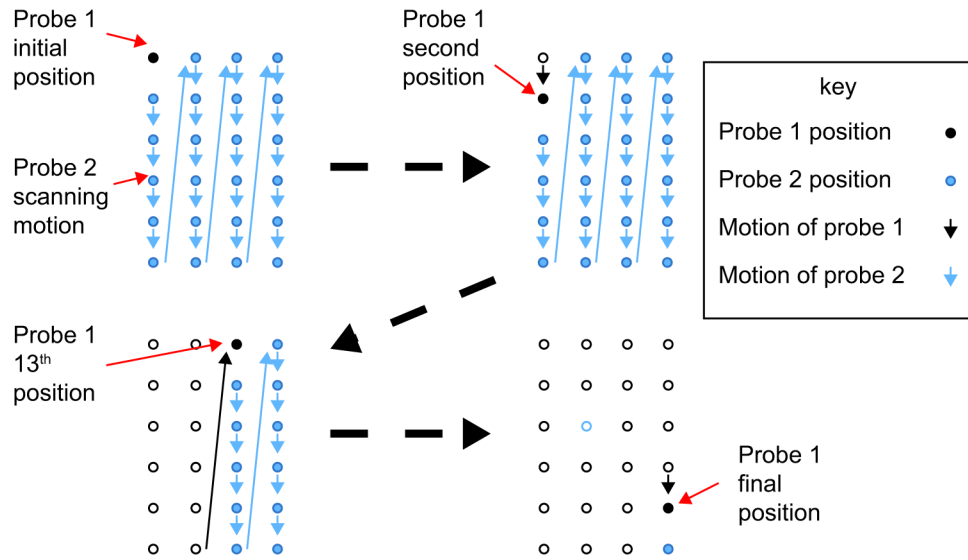


Figure 2—Example of scanning regime

The described probe movements are not strictly independent as there is a need for a systematic approach to getting the data. The scheme proposed in this guide is among preferable schemes in the sense that it is well suited for an implementation helping to avoid probe and probe holder collision (considering that the probe holder and positioning units are placed to the right and left of the device under test (DUT) according to Figure 3). It is required in general, to sample each possible point pair for all grid points, yielding

$(M \times N) \times \frac{(M \times N - 1)}{2}$ point pairs, which is also achieved by this scheme. If both tangential field components

are considered, the $(M \times N) \times \frac{(M \times N - 1)}{2}$ point pairs will lead to $2(M \times N)(M \times N - 1)$ measurements.

Figure 3 shows the hardware required for two probe scanning. Although the probe positioning and scanning equipment are not shown, they would be present in the actual set-up and suited to help ensuring mechanical accuracy, resolution, repeatability, and radio frequency (RF) accuracy according to what is described in the rest of this subclause (see also IEC TS 61967-3:2014).¹⁰ The field amplitude is sampled in the time domain using a high-speed digital oscilloscope or similar device and can then be converted to the frequency domain by using a fast Fourier transform. The oscilloscope analog bandwidth should be adequate for the wanted investigated frequency range (the maximum expected frequency content of the analyzed emission), no more than 6 GHz for the present guide. The oscilloscope real time sampling rate should be adequate to its analog bandwidth (four times may be sufficient). Time record length should be adequate to the type of

¹⁰ Information on references can be found in Clause 2.

emission under investigation: stationary or not. See what is reported in Clause 8 about cyclostationary emissions. The location of the probes also needs to be recorded by the data acquisition system. Ensure that there are no obstacles that could damage the probe within the desired scan area. The probe position can be found from the actuator encoders, or a laser tracker system may be incorporated. The whole process can be fully automated by a dedicated computer with suitable interface hardware. Further details can be found in 7.4 of IEC TS 61967-3:2014.

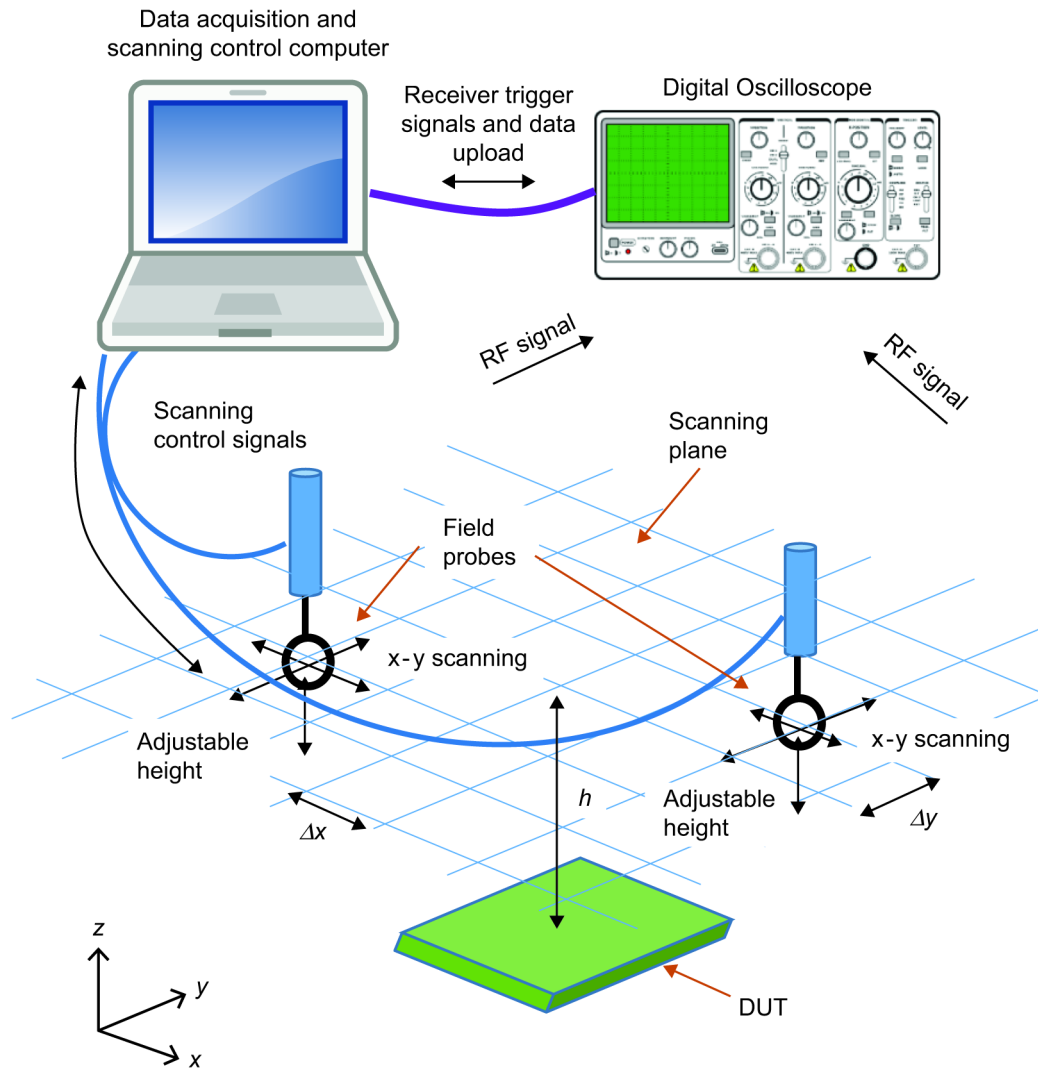


Figure 3 —Scanning equipment and layout

5.1.1 Mechanical accuracy

Near-field scanning is sensitive to the sampling position as the spatial distribution can vary widely. Errors caused by imprecise sampling and their correction have been studied by several authors for deterministic fields (see Russer and Braun [B13] and Russer et al. [B15]). It is far better to reduce any predictable errors in the measurement phase, especially for stochastic sources. The scanner position accuracy should be at least $1/10^{\text{th}}$ of the smallest probe size. In order to achieve the required position accuracy, the probe should be stationary during the sampling period and only move between sampling periods. The velocity profile of the probe movement should be such that this is reduced (i.e., there should be no mechanical vibrations induced by the scanning process). The mechanical rigidity of the scanner structure and position

repeatability should all be carefully checked. The motors for scanner movements should also be of a type that do not draw any current when stationary (this is to minimize interference with the sampling system).

Details about the adopted probe mounting and positioning system may be reported in the technical report.

5.1.2 RF accuracy

Some of the sources of uncertainty are discussed in IEEE Std 1720™-2012 [B7] and illustrated in Figure 4. Leakage from the RF equipment and cabling can interfere with the received signals and be a part of the cross-coupling between the probes. Multiple reflections and multi-path propagation can occur between the DUT and the probes. The scanning equipment can also be noise sources. It may be important to position RF absorbers around the equipment and cabling. In very sensitive measurements the DUT and probes should be located within an anechoic chamber and all other equipment located outside the anechoic chamber.

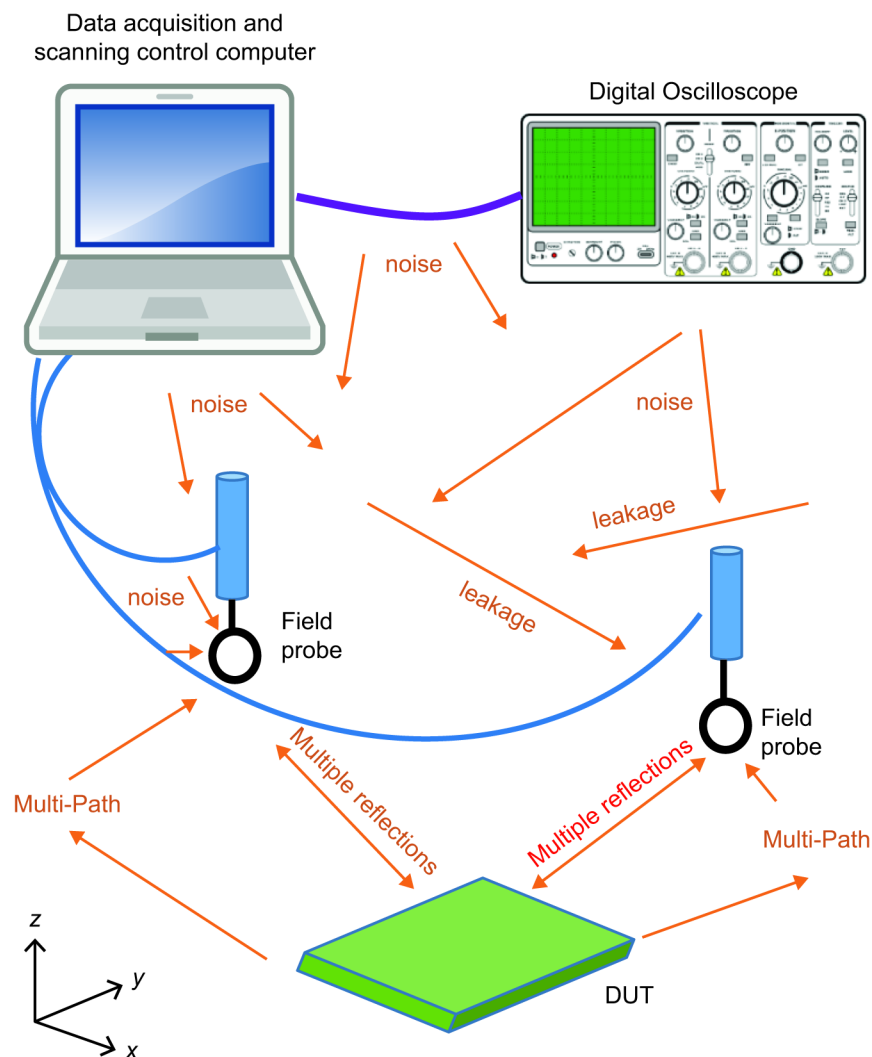


Figure 4 —Measurement sources of uncertainty