BS EN 62132-2:2011

BSI Standards Publication

Integrated circuits — Measurement of electromagnetic immunity

Part 2: Measurement of radiated immunity — TEM cell and wideband TEM cell method

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 62132-2:2011. It is identical to IEC 62132-2:2010.

The UK participation in its preparation was entrusted to Technical Committee EPL/47, Semiconductors.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

ISBN 978 0 580 57114 5

ICS 31.200

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 30 April 2011.

Amendments issued since publication

Amd. No.	Date	Text affected

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 62132-2

March 2011

ICS 31.200

English version

Integrated circuits - Measurement of electromagnetic immunity - Part 2: Measurement of radiated immunity - TEM cell and wideband TEM cell method

(IEC 62132-2:2010)

Circuits intégrés -
Mesure de l'immunité électromagnétique -
Partie 2: Mesure de l'immunité rayonnée -
Méthode de cellule TEM et cellule TEM à large bande
(CEI 62132-2:2010)

Integrierte Schaltungen -
Messung der elektromagnetischen Störfestigkeit -
Teil 2: Messung der Störfestigkeit bei Einstrahlungen -
TEM-Zellen- und Breitband-TEM-Zellenverfahren
(IEC 62132-2:2010)

This European Standard was approved by CENELEC on 2011-01-02. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and the United Kingdom.

CENELEC
European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Management Centre: Avenue Marnix 17, B - 1000 Brussels

Foreword

The text of document 47A/838/FDIS, future edition 1 of IEC 62132-2, prepared by SC 47A, Integrated circuits, of IEC TC 47, Semiconductor devices, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 62132-2 on 2011-01-02.

This part of EN 62132 is to be read in conjunction with EN 62132-1.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN and CENELEC shall not be held responsible for identifying any or all such patent rights.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2011-10-02
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2014-01-02

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 62132-2:2010 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

[7] IEC 61000-4-3:2006	NOTE	Harmonized as EN 61000-4-3:2006 (not modified).
IEC 61000-4-3:2006/A1:2007	NOTE	Harmonized as EN 61000-4-3:2006/A1:2008 (not modified).
[8] IEC 61000-4-6:2008	NOTE	Harmonized as EN 61000-4-6:2009 (not modified).
[9] IEC 61000-4-20:2003	NOTE	Harmonized as EN 61000-4-20:2003 (not modified).
[10] CISPR 16-1-1:2006	NOTE	Harmonized as EN 55016-1-1:2007 (not modified).
[12] CISPR 16-1-5:2003	NOTE	Harmonized as EN 55016-1-5:2004 (not modified).
[13] CISPR 16-2-1:2008	NOTE	Harmonized as EN 55016-2-1:2009 (not modified).
[15] CISPR 16-2-3:2006	NOTE	Harmonized as EN 55016-2-3:2006 (not modified).
[16] CISPR 16-2-4:2003	NOTE	Harmonized as EN 55016-2-4:2004 (not modified).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-131	2002	International Electrotechnical Vocabulary (IEV) - Part 131: Circuit theory	-	-
IEC 60050-161	1990	International Electrotechnical Vocabulary (IEV) - Chapter 161: Electromagnetic compatibility	-	-
IEC 61967-2	-	Integrated circuits - Measurement of electromagnetic emissions, 150 kHz to 1 GHz - Part 2: Measurement of radiated emissions - TEM cell and wideband TEM cell method	EN 61967-2	-
IEC 62132-1	2006	Integrated circuits - Measurement of electromagnetic immunity, 150 kHz to 1 GHz - Part 1: General conditions and definitions	EN 62132-1 + corr. November	2006 2006

CONTENTS

INTEGRATED CIRCUITS – MEASUREMENT OF ELECTROMAGNETIC IMMUNITY –

Part 2: Measurement of radiated immunity – TEM cell and wideband TEM cell method

1 Scope

This International Standard specifies a method for measuring the immunity of an integrated circuit (IC) to radio frequency (RF) radiated electromagnetic disturbances. The frequency range of this method is from 150 kHz to 1 GHz, or as limited by the characteristics of the TEM cell.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-131:2002, *International Electrotechnical Vocabulary (IEV) – Part 131: Circuit theory*

IEC 60050-161:1990, *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 61967-2, *Integrated circuits – Measurement of electromagnetic emissions, 150 kHz to 1 GHz – Part 2: Measurement of radiated emissions – TEM cell and wideband TEM cell method*

IEC 62132-1:2006, *Integrated circuits – Measurement of electromagnetic immunity, 150 kHz to 1 GHz – Part 1: General conditions and definitions*

3 Terms and definitions

For the purpose of this document, the definitions in IEC 62132-1, IEC 60050-131 and IEC 60050-161, as well as the following, apply.

3.1
transverse electromagnetic mode (TEM)
waveguide mode in which the components of the electric and magnetic fields in the propagation direction are much less than the primary field components across any transverse cross-section

3.2
TEM waveguide
open or closed transmission line system, in which a wave is propagating in the transverse electromagnetic mode to produce a specified field for testing purposes.

3.3
TEM cell

enclosed TEM waveguide, often a rectangular coaxial line, in which a wave is propagated in the transverse electromagnetic mode to produce a specified field for testing purposes. The outer conductor completely encloses the inner conductor

3.4
two-port TEM waveguide

TEM waveguide with input/output measurement ports at both ends

3.5
one-port TEM waveguide

TEM waveguide with a single input/output measurement port

NOTE Such TEM waveguides typically feature a broadband line termination at the non-measurement-port end.

3.6
characteristic impedance

for any constant phase wave-front, the magnitude of the ratio of the voltage between the inner conductor and the outer conductor to the current on either conductor

NOTE The characteristic impedance is independent of the voltage/current magnitudes and depends only on the cross-sectional geometry of the transmission line. TEM waveguides are typically designed to have a 50 Ω characteristic impedance. TEM waveguides with a 100 Ω characteristic impedance are often used for transient testing.

3.7
anechoic material

material that exhibits the property of absorbing, or otherwise reducing, the level of electromagnetic energy reflected from that material

3.8
broadband line termination

termination which combines a low-frequency discrete-component load, to match the characteristic impedance of the TEM waveguides (typically 50 Ω), and a high-frequency anechoic-material volume

3.9
primary (field) component

electric field component aligned with the intended test polarization

NOTE For example, in conventional two-port TEM cells, the septum is parallel to the horizontal floor, and the primary mode electric field vector is vertical at the transverse centre of the TEM cell.

3.10
secondary (field) component

in a Cartesian coordinate system, either of the two electric field components orthogonal to the primary field component and orthogonal to each other

4 General

The IC to be evaluated for EMC performance is referred to as the device under test (DUT). The DUT shall be mounted on a printed circuit board (PCB), referred to as the EMC test board. The EMC test board is provided with the appropriate measurement or monitoring points at which the DUT response parameters can be measured.

The EMC test board is clamped to a mating port (referred to as a wall port) cut in the top or bottom of a transverse electromagnetic mode (TEM) cell. Either a two-port TEM cell or a one-port TEM cell may be used. Within this standard, a two-port TEM cell is referred to as a TEM cell while a one-port TEM cell is referred to as a wideband (Gigahertz) TEM, or GTEM, cell.

The test board is not positioned inside the cell, as in the conventional usage, but becomes a part of the cell wall. This method is applicable to any TEM or GTEM cell modified to incorporate the wall port; however, the measured response of the DUT will be affected by many factors. The primary factor affecting the DUT's response is the septum to EMC test board (cell wall) spacing.

NOTE 1 This procedure was developed using a 1 GHz TEM cell with a septum to housing spacing of 45 mm and a GTEM cell with a septum to housing spacing of 45 mm at the centre of the wall port.

The EMC test board controls the geometry and orientation of the DUT relative to the cell and eliminates any connecting leads within the cell (these are on the backside of the board, which is outside the cell). For the TEM cell, one of the 50 Ω ports is terminated with a 50 Ω load. The other 50 Ω port for a TEM cell, or the single 50 Ω port for a GTEM cell, is connected to the output of an RF disturbance generator. The injected CW disturbance signal exposes the DUT to a plane wave electromagnetic field where the electric field component is determined by the injected voltage and the distance between the DUT and the septum of the cell. The relationship is given by

$$E = V/h$$

where

E is the field strength (V/m) within the cell;

V is the applied voltage (V) across the 50 Ω load; and

h is the height (m) between the septum and the centre of the IC package.

Rotating the EMC test board in the four possible orientations in the wall port of the TEM or GTEM cell is required to determine the sensitivity of the DUT to induced magnetic fields. Dependent upon the DUT, the response parameters of the DUT may vary (e.g. a change of current consumption, deterioration in function performance, waveform jitter, etc.) The intent of this test method is to provide a quantitative measure of the RF immunity of ICs for comparison or other purposes.

NOTE 2 Additional information on the use and characterization of TEM cells for radiated immunity testing can be found in IEC 61000-4-20.

5 Test conditions

The test conditions shall meet the requirements as described in IEC 62132-1.

6 Test equipment

6.1 General

The test equipment shall meet the requirements as described in IEC 62132-1. In addition, the following test equipment requirements shall apply.

6.2 Cables

Double shielded or semi-rigid coaxial cable may be required depending on the local RF ambient conditions.

6.3 RF disturbance source

The RF disturbance source may comprise an RF signal generator with a modulation function, an RF power amplifier, and an optional variable attenuator. The gain (or attenuation) of the RF disturbance generating equipment, without the TEM or GTEM cell, shall be known with a tolerance of ±0,5 dB.

6.4 TEM cell

The TEM cell used for this test procedure is a two-port TEM waveguide and shall be fitted with a wall port sized to mate with the EMC test board. The TEM cell shall not exhibit higher order modes over the frequency range being measured. For this procedure, the recommended TEM cell frequency range is 150 kHz to the frequency of the first resonance of the lowest higher order mode (typically <2 GHz). The frequency range being evaluated shall be covered using only a single cell.

The VSWR of the TEM cell over the frequency range being measured shall be less than 1,5. However, due to the potential for error when calculating the applied E-field, a TEM cell with a VSWR of less than 1,2 is preferred. A TEM cell with a VSWR less than 1,2 does not require field strength characterization. A TEM cell with a VSWR larger than or equal to 1,2 but less than 1,5 shall be characterized in accordance with the procedure in Annex A. The raw TEM cell VSWR data (over the frequency range of the measurement) shall be included in the test report. Measurement results obtained from a TEM cell with a VSWR of less than 1,2 will prevail over data taken from a TEM cell with a higher VSWR.

6.5 Gigahertz TEM cell

The Gigahertz, or wideband, TEM (GTEM) cell used for this test procedure is a one-port TEM waveguide and shall be fitted with a wall port sized to mate with the EMC test board. The GTEM cell shall not exhibit higher order modes over the frequency range being measured. For this procedure, the recommended GTEM cell frequency range is from 150 kHz to the frequency of the first resonance of the lowest higher order mode (typically >2 GHz). The frequency range being evaluated shall be covered using a single cell.

The VSWR of the GTEM cell over the frequency range being measured shall be less than 1,5. However, due to the potential for error when calculating the applied E-field, a GTEM cell with a VSWR of less than 1,2 is preferred. A GTEM cell with a VSWR less than 1,2 does not require field strength characterization. A GTEM cell with a VSWR larger than or equal to 1,2 but less than 1,5 shall be characterized in accordance with the procedure in Annex A. The raw GTEM cell VSWR data (over the frequency range of the measurement) shall be included in the test report. Measurement results obtained from a GTEM cell with a VSWR of less than 1,2 will prevail over data taken from a GTEM cell with a higher VSWR.

6.6 50 Ω termination

A 50 Ω termination with a VSWR less than 1,1 and sufficient power handling capabilities over the frequency range of measurement is required for the TEM cell measurement port not connected to the RF disturbance generator.

6.7 DUT monitor

The performance of the DUT shall be monitored for indications of performance degradation. The monitoring equipment shall not be adversely affected by the injected RF disturbance signal.

7 Test set-up

7.1 General

The test set-up shall meet the requirements as described in IEC 62132-1. In addition, the following test set-up requirements shall apply.

7.2 Test set-up details

The EMC test board shall be mounted in the wall port of the TEM cell or GTEM cell with the DUT facing the septum as shown in Figure 1.

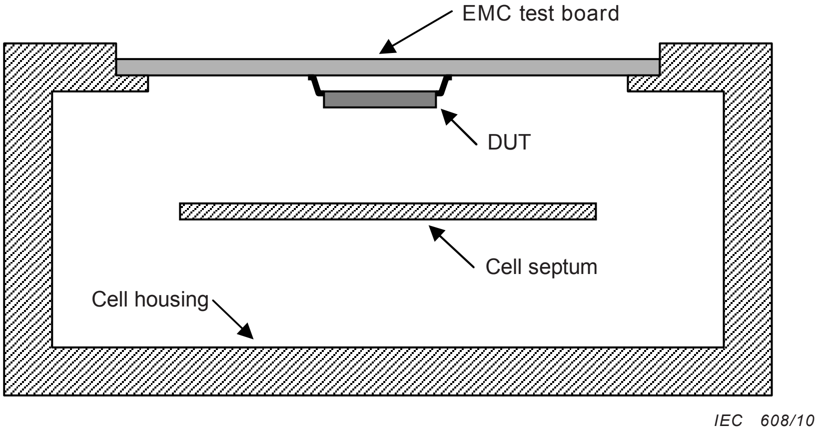


Figure 1 – TEM and GTEM cell cross-section

The test setup shall be as described in Figure 2 and Figure 3 for TEM cell and GTEM cell test configurations, respectively. One of the TEM cell measurement ports shall be terminated with a 50 Ω load. The remaining TEM cell measurement port, or the single GTEM measurement port, shall be connected to the output port of the power amplifier.

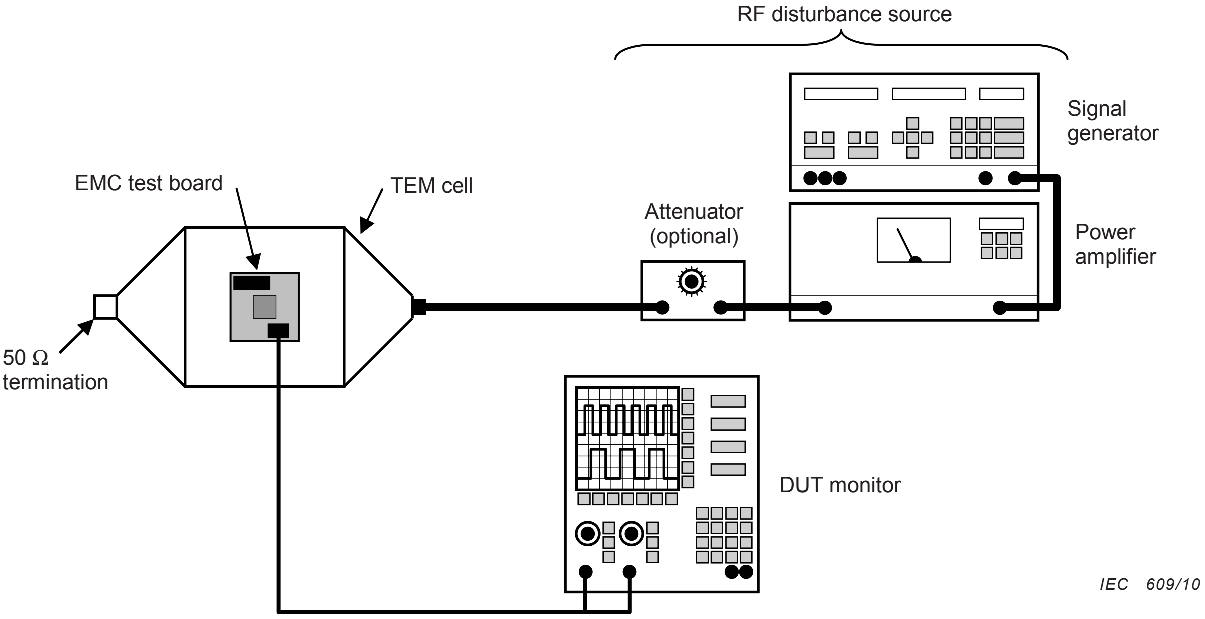


Figure 2 – TEM cell test set-up

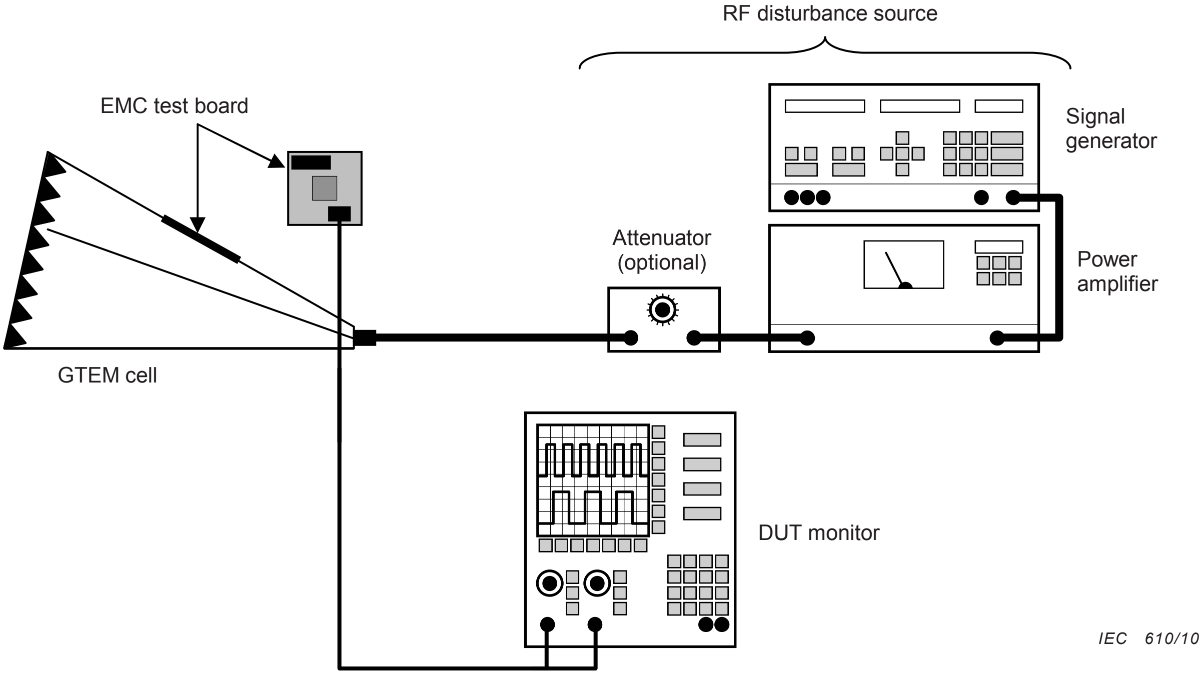


Figure 3 – GTEM cell test set-up

7.3 EMC test board

The EMC test board shall be designed in accordance with the requirements in IEC 61967-2.

8 Test procedure

8.1 General

The test procedure shall be in accordance with IEC 62132-1 except as modified herein. These default test conditions are intended to assure a consistent test environment. The following steps shall be performed:

a) field strength characterization (see Annex A);
b) immunity measurement (see 8.2).

If the users of this procedure agree to other conditions, these conditions shall be documented in the test report.

8.2 Immunity measurement

8.2.1 General

With the EMC test board energized and the DUT being operated in the intended test mode, measure the immunity to the injected RF disturbance signal over the desired frequency range.

8.2.2 RF disturbance signals

The RF disturbance signals shall be

- CW (continuous wave) and
- AM (amplitude modulated CW) at 80 % depth by a 1 kHz sine wave or (optionally) pulse modulated at 100 % depth with 50 % duty cycle and 1 kHz pulse repetition rate.

NOTE The optional pulse modulation requirement is typically about 6 dB more severe than the stated amplitude modulation requirement.

8.2.3 Test frequencies

The RF immunity of the DUT shall be evaluated at a number of discrete test frequencies from 150 kHz to 1 GHz, or as limited by the characteristics of the TEM cell. The frequencies to be tested shall be generated from the requirements specified in Table 2 of IEC 62132-1.

In addition, the RF immunity of the DUT shall be evaluated at critical frequencies. Critical frequencies are frequencies that are generated by, received by, or operated on by the DUT. Critical frequencies include but are not limited to crystal frequencies, oscillator frequencies, clock frequencies, data frequencies, etc.

8.2.4 Test levels and dwell time

The applied test level shall be increased in steps until a malfunction is observed or the maximum signal generator setting is reached. The step size shall be documented in the test report.

At each test level and frequency, the RF disturbance signal shall be applied for a minimum of 1 s (or at least the time necessary for the DUT to respond and the monitoring system to detect any performance degradation).

8.2.5 DUT monitoring

The DUT shall be monitored for indications of susceptibility using the appropriate test equipment and as required in IEC 62132-1.

8.2.6 Detail procedure

8.2.6.1 Field strength characterization

At each frequency to be tested, the signal generator setting to achieve the desired electric field level or levels shall be determined as described in Annex A.

8.2.6.2 Immunity measurement

The test flow, including major steps, is described in Figure 4. One of two strategies may be employed in performing this measurement as follows:

a) the output of the RF disturbance generator shall be set at a low value (e.g. 20 dB below the desired limit) and slowly increased up to the desired limit while monitoring the DUT for performance degradation. Any performance degradation at or below the desired limit shall be recorded;

b) the output of the RF disturbance generator shall be set at the desired performance limit while monitoring the DUT for performance degradation. Any performance degradation at the desired limit shall be recorded. The output of the RF disturbance generator shall then be reduced until normal function returns. The output of the RF disturbance generator shall then be increased until the performance degradation occurs again. This level shall also be recorded.

NOTE The DUT may respond differently to each of the above methods. In such a case, a method in which the interference signal is ramped up as well as down may be required.

The RF immunity measurement shall be performed in each of the four possible orientations resulting in four separate sets of data. The first measurement is made with the IC test board mounted in an arbitrary orientation of the IC in the cell wall port. The second measurement is made with the IC test board rotated 90 degrees from the orientation in the first measurement. For each of the third and fourth measurements, the test board is rotated again to ensure immunity is measured in all four possible orientations. The four sets of data shall be documented in the test report.

9 Test report

The test report shall be in accordance with the requirements of IEC 62132-1.

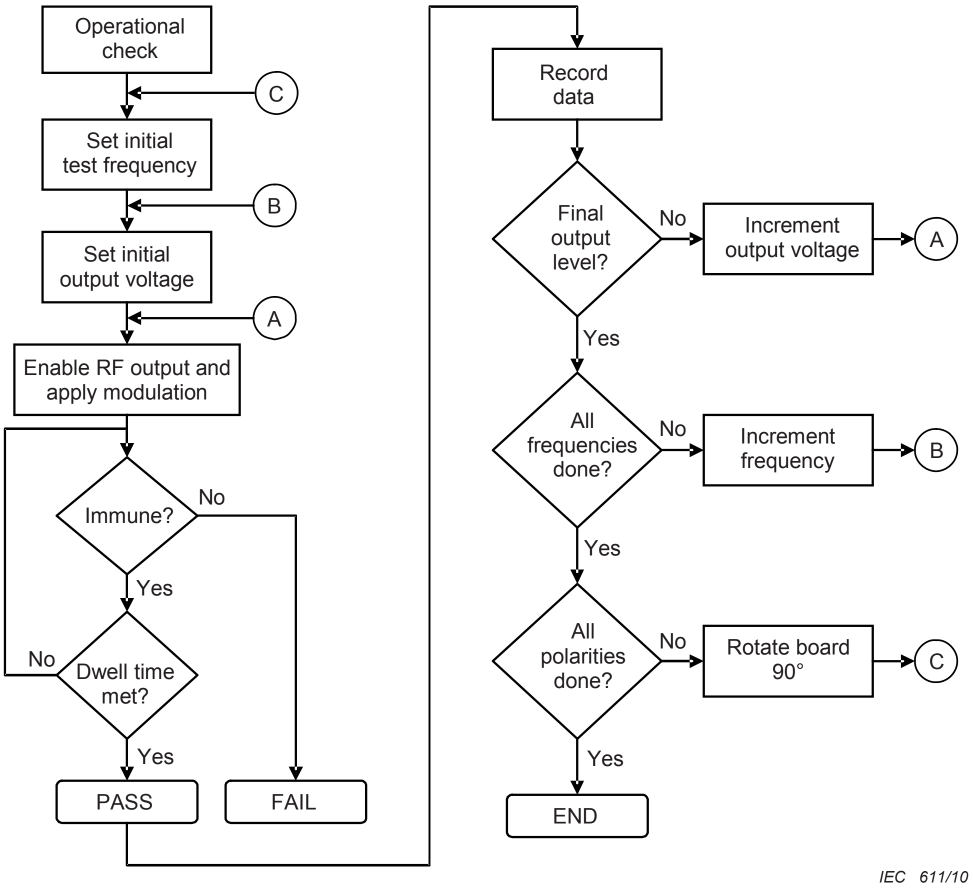


Figure 4 – Immunity measurement procedure flowchart

Annex A
(normative)

Field strength characterization procedure

A.1 General

The signal level setting of the RF disturbance generator required to achieve the desired electric field level within the TEM or GTEM cell shall be determined in accordance with this procedure. This measurement shall be performed at each standard frequency (either linear or logarithmic as used in the actual test) as determined in accordance with 8.2.3. The RF disturbance signal used for characterization shall be a CW signal (e.g. no modulation shall be applied).

A.2 Electric (E) field strength characterization

A.2.1 Electric field characterization test fixture

The electric field can be measured by using a small monopole antenna at the centre location of the characterization board as shown in Figure A.1. It is recommended that the diameter of the top plate capacitive load shall be small (e.g. an area of approximately 0,001 m^2 or 10 cm^2) and either circular or square. The antenna top plate shall be kept parallel to the top metallic surface of the characterization board, which may be either a printed circuit board or metal plate, at a height of 3,0 mm ±0,1 mm. This top plate will yield a capacitance of about 3 pF. The centre of this plate shall be fed to a surface-mount, coaxial bulkhead connector that in turn shall be connected to the 50 Ω input impedance of an RF voltmeter or spectrum analyser. The resulting high-pass circuit results in an incremental slope of 20 dB/decade over the full frequency range up to 1 GHz.

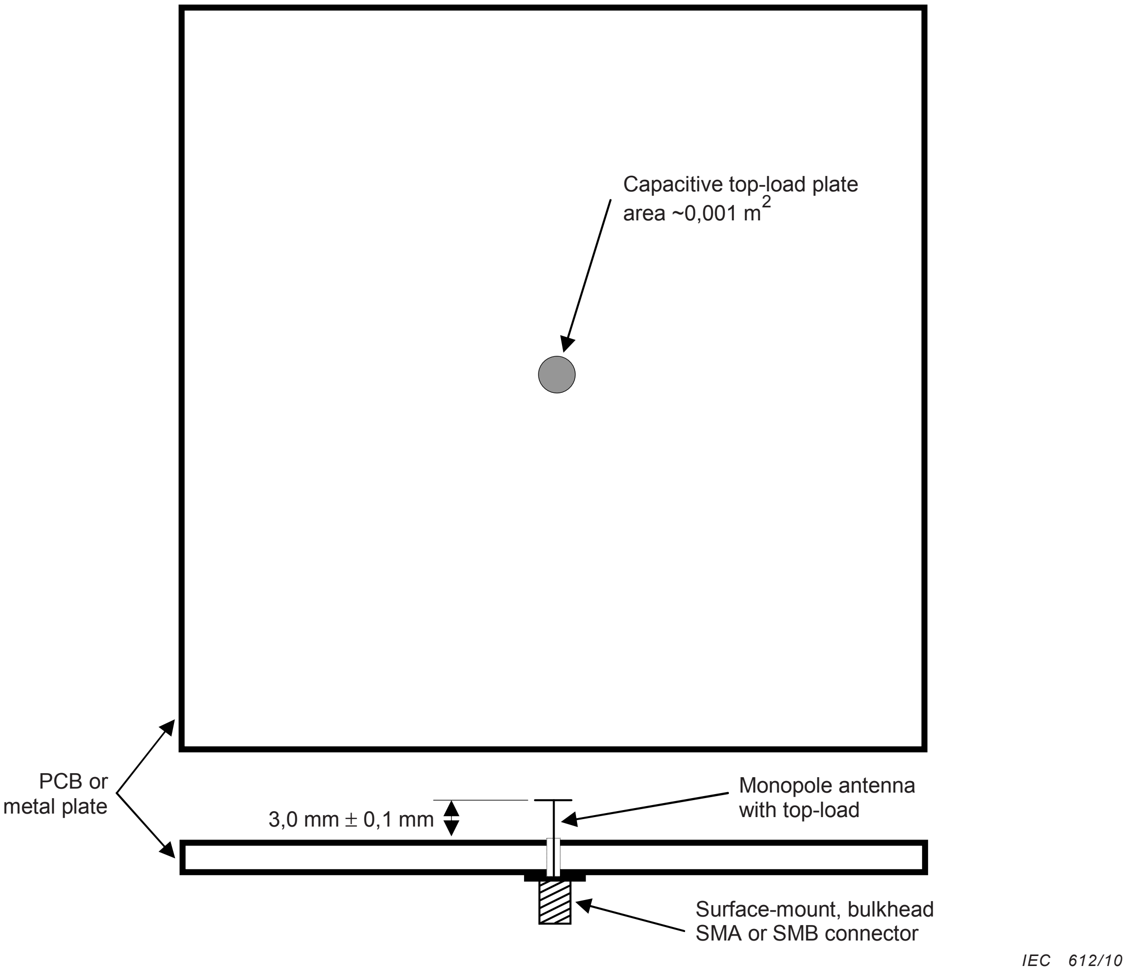
The characterization board shall be identical in size to the EMC test board to be used during the actual radiated immunity measurements as specified in IEC 62132-1. The bulkhead connector shall be a 50 Ω type, either SMA or SMB, and placed in the exact centre of the characterization board.

The PCB shall be constructed with at least one conductive layer. The conductive layer should cover the entire board forming a solid ground plane. The SMA or SMB connector should be mounted on the side of the PCB opposite the ground plane, with its outer conductor connected to the ground plane and the centre conductor passing through an unplated, through-hole penetration to the other side of the board. Additional conductive PCB layers should be assigned to ground and connected using multiple vias as shown for the EMC test board in IEC 62132-1.

NOTE Tolerances for top plate area, capacitance and board location are under development.

A.2.2 Capacitance measurement

The top plate capacitance of the monopole shall be measured separately to assure a capacitance of 3 pF. The capacitance shall be measured with the characterization test fixture inserted into the TEM cell. With the impedance reference plane set at the bulkhead coaxial connector mounted at the location where the device/IC is to be positioned, the monopole is mounted to this bulkhead connector and the impedance (i.e. capacitance) is measured at a reference frequency of 10 MHz. This measurement is made to ensure that the physical length of the wire (i.e. the inductance) does not affect the characterization.



In the case of a PCB, a ground plane is required on both sides

Figure A.1 – *E* field characterization test fixture

A.2.3 Electric field strength calculation

The voltage induced at the output of the monopole antenna is given by

$$V_{\text{ant}} = h_{\text{ant}} \times E_{\text{tem}} \tag{A.1}$$

where

V_{ant} is the voltage at the test fixture output port, expressed in volts (V), by the internal electric field;

E_{tem} is the electric field within the TEM or GTEM cell, expressed in volts per meter (V/m);

h_{ant} is the height of the monopole antenna, expressed in meters (m).

In addition, the electric field in the TEM or GTEM cell is also given by

$$E_{\text{tem}} = \frac{V_{\text{tem}}}{h_{\text{sep}}} \Rightarrow V_{\text{tem}} = E_{\text{tem}} \times h_{\text{sep}} \tag{A.2}$$

where

V_{tem} is the voltage at the port of the TEM or GTEM cell, expressed in volts (V);

h_{sep} is the distance from the antenna top load to the inner septum of the TEM or GTEM cell, expressed in meters (m).

So that the resulting transfer function (S21) is given by

$$\text{S21} = \frac{V_{\text{ant}}}{V_{\text{tem}}} = \frac{h_{\text{ant}}}{h_{\text{sep}}} \times \frac{50}{\sqrt{(50)^2 + |Z_{\text{ant}}|^2}} \tag{A.3}$$

where

$|Z_{\text{ant}}|$ is the magnitude of the antenna impedance, given by $|1/(j\omega C)|$ and expressed in ohms (Ω), neglecting resistance.

The antenna impedance is given by

$$|Z_{\text{ant}}| = \frac{1}{\omega C_{\text{ant\_meas}}} = \frac{1}{2\pi f \times C_{\text{ant\_meas}}} \tag{A.4}$$

where

$C_{\text{ant\_meas}}$ is the measured antenna capacitance, expressed in farads (F).

A.2.4 Example electric field strength calculation

At 10 MHz, solving for V_{ant} as a function of E_{tem} using Equation (A.1) gives

$$V_{\text{ant}} = \left(3 \times 10^{-3}\right) \times E_{\text{tem}}$$

For a monopole antenna with a measured capacitance of 3 pF, the antenna impedance is calculated from Equation (A.4):

$$|Z_{\text{ant,10MHz}}| = \frac{1}{2\pi \times (10 \times 10^{6}\,\text{Hz}) \times (3 \times 10^{-12}\,\text{F})} = 5305\ \Omega$$

So the resulting transfer function at 10 MHz for h_{sep} = 45 mm – 3 mm = 42 mm is calculated using Equation (A.3) giving

$$\text{S21} = \frac{3 \times 10^{-3}\,\text{m}}{42 \times 10^{-3}\,\text{m}} \cdot \frac{50}{\sqrt{(50)^2 + (5305)^2}} = 673{,}9 \times 10^{-6}$$

Converting the S21 value to decibels gives the final result as

$$\text{S21}_{\text{dB}} = 20 \cdot \log\left(673{,}9 \times 10^{-6}\right) = -63{,}43\ \text{dB}$$

The electric field to voltage transfer function given in Equation (A.3) and converted to decibels, for the parameters given above, is plotted in Figure A.2 and is suited for characterization up to 1 GHz. The value of the transfer function shall be compensated for the TEM cell septum-to-device height as given in A.4.

Due to the non-ideal nature of TEM cell and GTEM cell devices, a maximum deviation of 6 dB is allowed for 3 % of the frequencies determined in accordance with 8.2.3. For all other frequencies, the performance of the field strength shall be within 1 dB of the ideal curve given in Figure A.2. Frequencies at which the deviation is greater than 1 dB shall be listed in the test report.

NOTE Any failure at a frequency with a deviation of greater than 1 dB should be ignored during qualification testing.

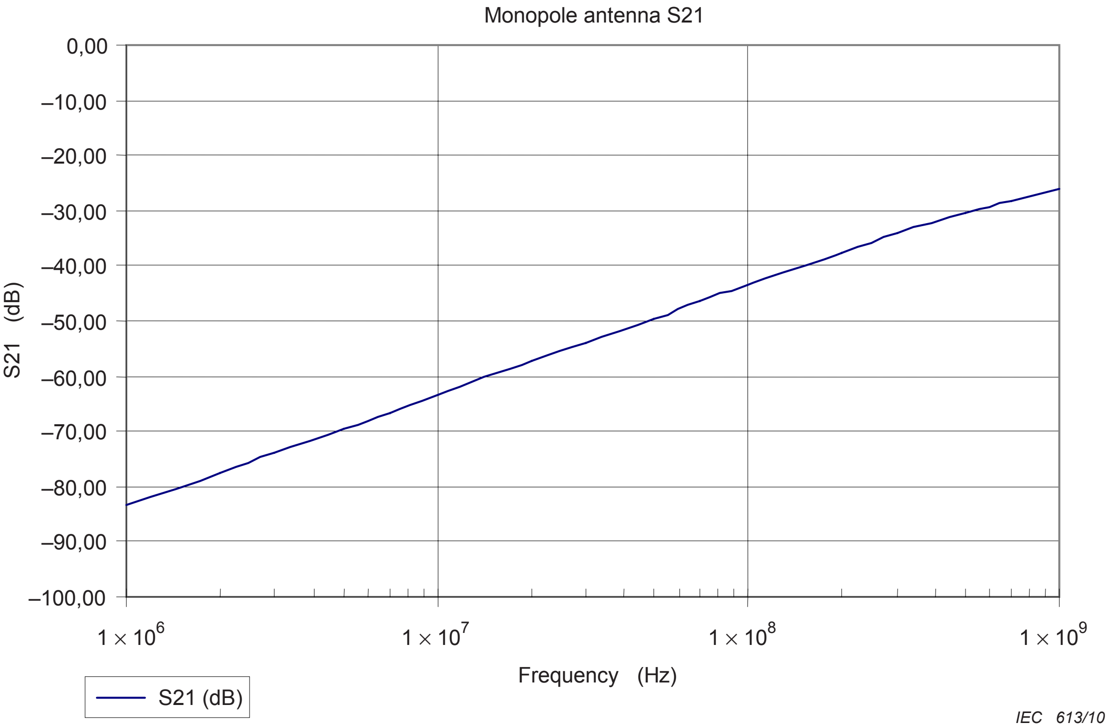


Figure A.2 – The electric field to voltage transfer function

When the characterization needs to be performed at higher frequencies (>1 GHz), the parameters of the probe shall be adjusted such that the linear behavior is extended accordingly (at the cost of sensitivity at the lower frequencies).

A.3 Magnetic (*H*) field strength characterization

A.3.1 Magnetic field strength characterization test fixture

The magnetic field can be measured by using a small loop antenna at the centre location of the EMC test board as shown in Figure A.3. A magnetic loop shall be constructed using wire with a 1 mm ±0,1 mm diameter. The loop shall have a separation height of 3,3 mm ±0,1 mm from the top conductive surface of the test fixture. The length of the loop shall be 30 mm ±0,1 mm, which results in an effective loop area of approximately 99 mm^2.

For the characterization, the loop shall be oriented in parallel to the propagation direction of the EM wave in the TEM cell or GTEM cell.

The characterization board shall be identical in size to the EMC test board to be used during the actual radiated immunity measurements as specified in IEC 62132-1. The bulkhead connector shall be a 50 Ω type, either SMA or SMB. The bulkhead surface-mount, coaxial connector shall be mounted 15 mm ±1,0 mm off-centre of the EMC test board.

The PCB shall be constructed with at least one conductive layer. The conductive layer should cover the entire board forming a solid ground plane. The SMA or SMB connector should be mounted on the side of the PCB opposite the ground plane, with its outer conductor connected to the ground plane and the centre conductor passing through an unplated, through-hole penetration to the other side of the board. Additional conductive PCB layers should be assigned to ground and connected using multiple vias as shown for the EMC test board in IEC 62132-1.

A.3.2 Magnetic field strength calculation

The voltage induced at the output of the loop antenna is given by

$$V_{\mathrm{ant}} = N \times \frac{\mathrm{d}\Phi}{\mathrm{d}t} \tag{A.5}$$

where

$$N = 1$$

$$\Phi(t) = \Phi \times \sin(\omega t) \Rightarrow \frac{\mathrm{d}\Phi}{\mathrm{d}t} = \Phi \times \omega$$

$$\Phi = B \times A_{\mathrm{loop}}$$

$$B = \mu_{\mathrm{o}} \times H$$

$$H = \frac{E}{Z_{\mathrm{o}}}$$

$$\omega = 2\pi f$$

Substituting back into Equation (A.5) gives

$$V_{\mathrm{ant}} = \left(\frac{E_{\mathrm{tem}}}{Z_{\mathrm{o}}}\right) \times \mu_{\mathrm{o}} \times A_{\mathrm{loop}} \times 2\pi f \tag{A.6}$$

where

V_{ant}	is the voltage at the test fixture output port, expressed in volts (V), by the internal electric field;
E_{tem}	is the electric field within the TEM or GTEM cell, expressed in volts per meter (V/m);
Z_{o}	is the characteristic impedance of free space (120 π Ω or 377 Ω);
μ_{o}	is the permeability of free space ($4\pi \times 10^{-7}$ H/m);
A_{loop}	is the area of the loop antenna, expressed in square meters (m^2);
f	is the frequency of interest, expressed in Hertz (Hz).

In addition, the electric field in the TEM or GTEM cell is also given by

$$E_{\mathrm{tem}} = \frac{V_{\mathrm{tem}}}{h_{\mathrm{sep}}} \Rightarrow V_{\mathrm{tem}} = E_{\mathrm{tem}} \times h_{\mathrm{sep}} \tag{A.7}$$

where

V_{tem}	is the voltage at the port of the TEM or GTEM cell, expressed in volts (V);

h_{sep} is the distance from the antenna to the inner septum of the TEM or GTEM cell, expressed in meters (m).

So that the resulting transfer function (S21) is given by

$$\mathrm{S21} = \frac{V_{\mathrm{ant}}}{V_{\mathrm{tem}}} = \frac{\mu_{\mathrm{o}} \times A_{\mathrm{loop}} \times 2\pi f}{Z_{\mathrm{o}} \times h_{\mathrm{sep}}} \times \frac{50}{\sqrt{(50)^2 + (|Z_{\mathrm{ant}}|)^2}} \qquad \text{(A.8)}$$

where

$|Z_{\mathrm{ant}}|$ is the magnitude of the antenna impedance, given by $|j\omega L|$ and expressed in ohms (Ω), neglecting resistance.

The antenna impedance is given by

$$|Z_{\mathrm{ant}}| = \varpi L_{\mathrm{ant\_meas}} = 2\pi f \times L_{\mathrm{ant\_meas}} \qquad \text{(A.9)}$$

where

$L_{\mathrm{ant\_meas}}$ is the measured inductance of the small loop antenna, expressed in henrys [H].

A.3.3 Example magnetic field strength calculation

For the specified loop antenna, the loop area is

$$A_{\mathrm{loop}} = h_{\mathrm{loop}} \times l_{\mathrm{loop}} = \left(3{,}3 \times 10^{-3}\,\mathrm{m}\right) \times \left(30 \times 10^{-3}\,\mathrm{m}\right) = 99 \times 10^{-6}\ \mathrm{m}^2$$

where

h_{loop} is the height of the loop over the PCB, expressed in meters (m).

l_{loop} is the length of the loop, expressed in meters (m).

At 10 MHz, solving for V_{ant} as a function of E_{tem} using Equation (A.6) gives

$$V_{\mathrm{ant}} = \left(\frac{E_{\mathrm{tem}}}{377}\right) \times \left(4\pi \times 10^{-7}\right) \times \left(99 \times 10^{-6}\,\mathrm{m}^2\right) \times \left(2\pi \times 10 \times 10^{6}\,\mathrm{Hz}\right) = E_{\mathrm{tem}} \times \left(20{,}1 \times 10^{-6}\right)$$

For a loop antenna with a measured inductance of 73 nH, the impedance is calculated using Equation (A.9) giving

$$Z_{\mathrm{ant,10MHz}} = 2\pi \times \left(10 \times 10^{6}\,\mathrm{Hz}\right) \cdot \left(73 \times 10^{-9}\,\mathrm{H}\right) = 4{,}58\,\Omega$$

So the resulting transfer function (S21) at 10 MHz for h_{sep} = 45 mm – 3,3 mm = 41,7 mm is calculated using Equation (A.8) giving

$$\mathrm{S21} = \frac{\left(4\pi \times 10^{-7}\right) \times \left(99 \times 10^{-6}\,\mathrm{m}^2\right) \times \left(2\pi \times 10 \times 10^{6}\,\mathrm{Hz}\right)}{377 \times 41{,}7 \cdot 10^{-3}\,\mathrm{m}} \cdot \frac{50}{\sqrt{(50)^2 + (4{,}58)^2}} = 495{,}1 \times 10^{-6}$$

Converting the S21 value to decibels gives the final result as

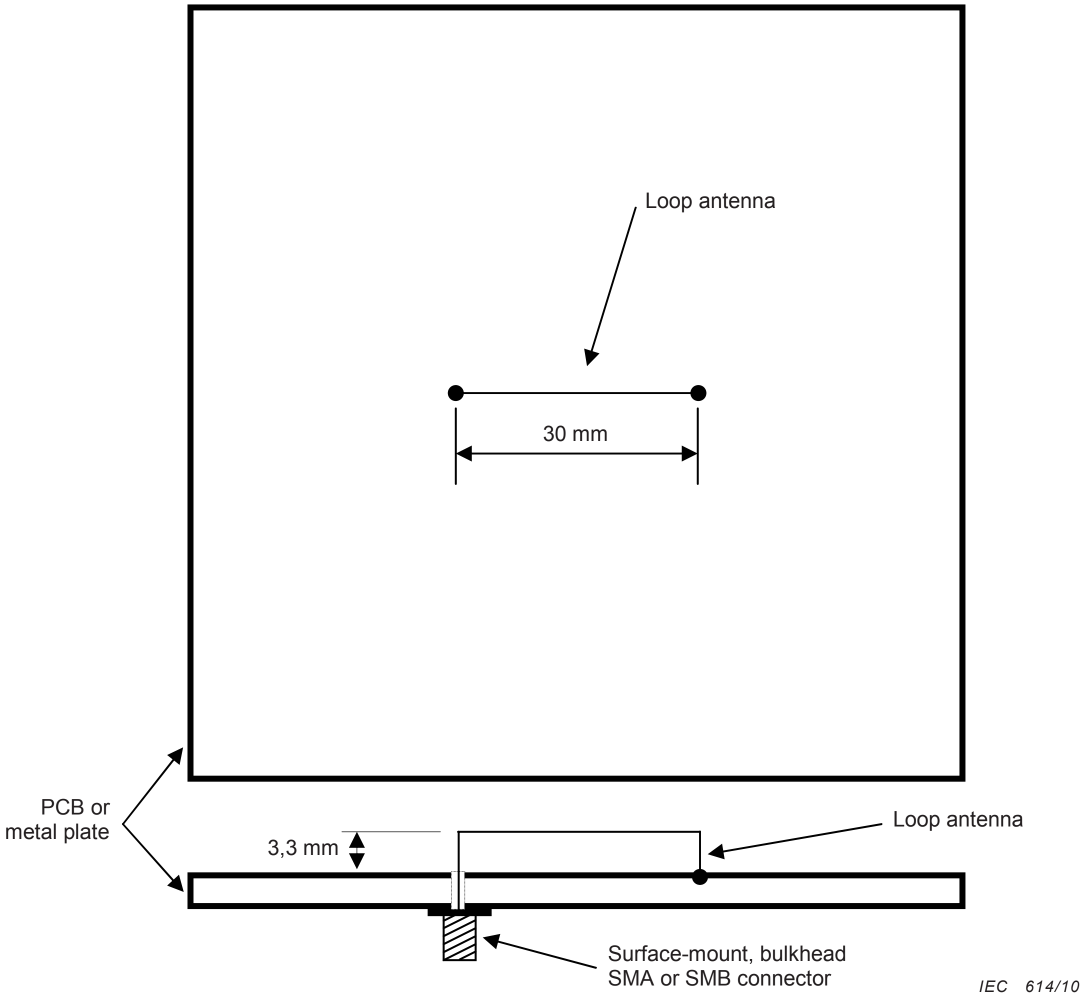
$$\mathrm{S21}_{\mathrm{dB}} = 20 \cdot \log\left(495{,}15 \times 10^{-6}\right) = -66{,}11\ \mathrm{dB}$$

The magnetic field to voltage transfer function given in Equation (A.8) and converted to decibels, for the parameters given above, is plotted in Figure A.4 and is suited for characterization up to 1 GHz. The value of the transfer function shall be compensated for the TEM cell septum-to-device height as given in A.4.

Due to the non-ideal nature of TEM cell and GTEM cell devices, a maximum deviation of 6 dB is allowed for 3 % of the frequencies determined in accordance with 8.2.3. For all other frequencies, the performance of the field strength shall be within 1 dB of the ideal curve given in Figure A.4. Frequencies at which the deviation is greater than 1 dB shall be listed in the test report.

NOTE 1 Any failure at a frequency with a deviation of greater than 1 dB should be ignored during qualification testing.

NOTE 2 Since the magnetic field to voltage transfer function is not continuously proportional with frequency for the parameters given above, the electric field to voltage characterization given in A.2 is preferred.



In the case of a PCB, a ground plane is required on both sides

Figure A.3 – *H* field characterization test fixture

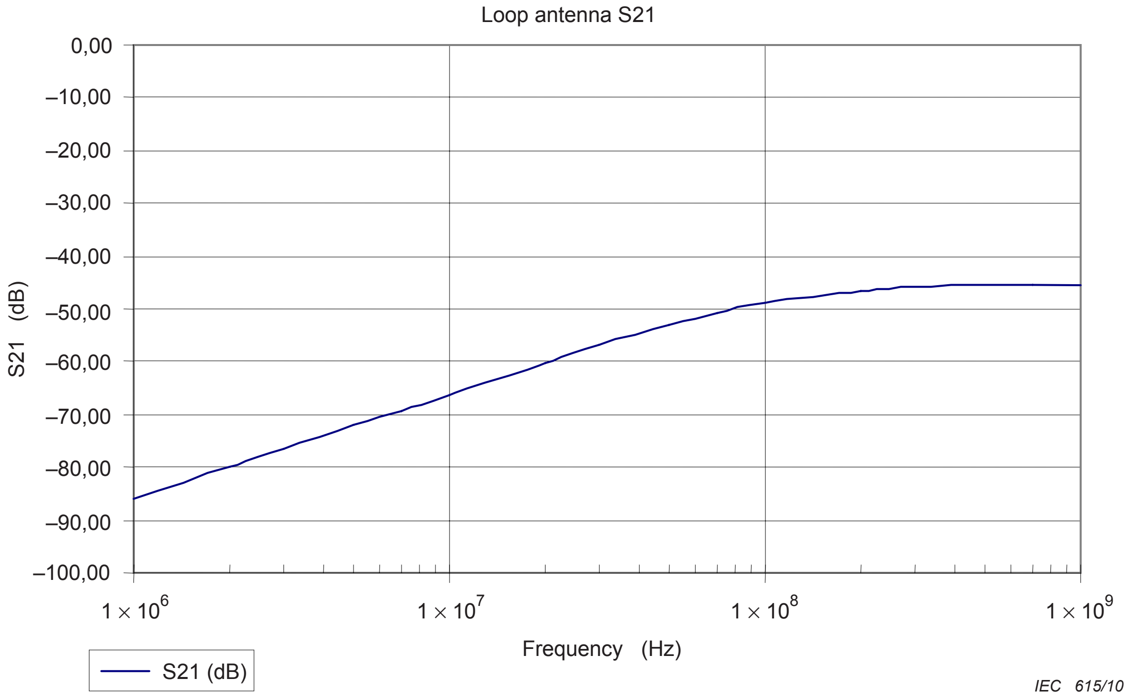


Figure A.4 – The magnetic field to voltage transfer function

A.4 Package height correction

With the above calculations, it is assumed the field strength is homogeneous over the area of integration. However, when a device/IC is packaged with the leadframe or heat spreader grounded to the test board reference plane, a small correction shall be applied for the field strength due to the change of height between septum and the “grounded” metal in the package. For a septum to device height greater than the standard 45 mm, this correction can be ignored. When the septum to device height is less than 45 mm, the local field strength is significantly affected and shall be corrected.

Example:

Septum height = 30 mm

Diepad height = 1,5 mm

E-field correction = Septum height / (Septum height – diepad height) = 105 % ≈ 0,5 dB

A.5 Characterization set-up

The test set-up for characterization is similar to Figure 1 and Figure 2 except that the EMC test board and the DUT monitor are replaced by the characterization board and a measurement device. The SMA or SMB connector of the characterization board is connected via a 50 Ω coaxial cable to the 50 Ω input of a measurement device such as an RF spectrum analyzer, RF voltmeter or power meter. Alternately, a vector network analyzer may be used to perform the characterization by providing both the stimulus (RF disturbance source) and measurement in a single device.

A.6 Characterization procedure

For each frequency of interest, subtract the value of the measured signal from the value of the injected signal and compare to the theoretical value given by the appropriate S21 equation. All values shall be in decibels.

Annex B
(informative)

TEM CELL and wideband TEM cell descriptions

B.1 TEM cell

The TEM cell offers a broadband method of measuring either immunity of a DUT to fields generated within the cell or radiated emissions from a DUT placed within the cell. It eliminates the use of conventional antennas with their inherent measurement limitations of bandwidth, non-linear phase, directivity and polarisation. The TEM (Transverse Electromagnetic Mode) cell is an expanded transmission line that propagates a TEM wave from an external or internal source. This wave is characterised by transverse orthogonal electric (E) and magnetic (H) fields, which are perpendicular to the direction of propagation along the length of the cell or transmission line. This field simulates a planar field generated in free space with impedance of 377 Ω. The TEM mode has no low frequency cut-off. This allows the cell to be used at frequencies as low as desired. The TEM mode also has linear phase and constant amplitude response as a function of frequency. This makes it possible to use the cell to generate or detect a known field intensity. The upper useful frequency for a cell is limited by distortion of the test signal caused by resonances and multi-moding that occur within the cell. These effects are a function of the physical size and shape of the cell.

For example, the 1 GHz TEM cell is of a size and shape, with impedance matching at the input and output feed points of the cell, that limits the VSWR to less than 1,5 up to its rated frequency. The cell is tapered at each end to adapt to conventional 50 Ω coaxial connectors and is equipped with an access port to accommodate the IC test board. The first resonance is demonstrated by a high VSWR over a narrow frequency range. The high Q of the cell is responsible for this high VSWR. A cell verified for field generation to a maximum frequency will also be suitable for emission measurements to this frequency.

B.2 Wideband TEM or Gigahertz TEM (GTEM) cell

The wideband TEM, or GTEM, cell is an expanded transmission line that does not transition back to a 50 Ω feed as in a conventional TEM cell but continuously expands and is terminated with a septum load and RF absorber material. This cell avoids the moding limitations of conventional TEM cells so that its usable upper frequency is limited not by its dimensions, but by the characteristics of the RF absorber and septum termination. A wideband TEM cell may be almost any practical size with a usable frequency range up to 18 GHz.

GTEM cells offer the potential to extend the upper frequency limit of a radiated immunity measurement beyond the 1 GHz to 2 GHz limitation of a TEM cell. An extended frequency limit is necessary, for example, to enable the proper evaluation of ICs that utilize clock frequencies near or above 1 GHz.

In addition, the larger size of the GTEM cell offers the ability to evaluate an IC that requires a PCB larger than the default size defined in IEC 62132-1. Like any other modification to this test method, the PCB size may be extended as agreed between the manufacturer and user and should be carefully documented in the test report.

Bibliography

[1] Muccioli, J.P., North, T.M., Slattery, K.P., "Characterisation of the RF Immunity from a Family of Microprocessors Using a 1 GHz TEM Cell", 1997 IEEE International Symposium on Electromagnetic Compatibility, August 1997.

[2] Engel, A., "Model of IC Immunity into a TEM Cell", 1997 IEEE International Symposium on Electromagnetic Compatibility, August 1997.

[3] Muccioli, J.P., North, T.M., Slattery, K.P., "Investigation of the Theoretical Basis for Using a 1 GHz TEM Cell to Evaluate the Radiated Immunity from Integrated Circuits", 1996 IEEE International Symposium on Electromagnetic Compatibility, August 1996.

[4] Goulette, R.R., Crawhall, R.J., Xavier, S.K., "The Determination of Radiated Immunity Limits for Integrated Circuits within Telecommunications Equipment", IEICE Transactions on Communications, Vol. E75-B, No. 3, March 1992.

[5] Goulette, R.R., "The Measurement of Radiated Immunity from Integrated Circuits", 1992 IEEE International Symposium on Electromagnetic Compatibility, August 1992.

[6] Koepke, G.H., Ma, M.T., "A New Method for Determining the Emission Characteristics of an Unknown Interference Source", Proceedings of the 5th International Zurich Symposium & Technical Exhibition on EMC, March 1983, pp. 35-40.

[7] IEC 61000-4-3:2006, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*
Amendment 1 (2007)

[8] IEC 61000-4-6:2008, *Electromagnetic compatibility (EMC) – Part 4-6: Testing and measurement techniques – Immunity to conducted disturbances, induced by radio-frequency fields*

[9] IEC 61000-4-20:2003, *Electromagnetic compatibility (EMC) Part 4: Testing and measurement techniques – Emission and immunity testing in transverse electromagnetic (TEM) waveguides*

[10] CISPR 16-1-1:2007, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus.*

[11] CISPR 16-1-2:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances*

[12] CISPR 16-1-5:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-5: Radio disturbance and immunity measuring apparatus – Antenna calibration test sites for 30 MHz to 1 000 MHz*

[13] CISPR 16-2-1:2008, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-1: Methods of measurement of disturbances and immunity – Conducted disturbance measurements*

[14] CISPR 16-2-2:2005, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-2: Methods of measurement of disturbances and immunity – Measurement of disturbance power*

[15] CISPR 16-2-3:2006, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-3: Methods of measurement of disturbances and immunity – Radiated disturbance measurements*

[16] CISPR 16-2-4:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements*

This page deliberately left blank

This page deliberately left blank

British Standards Institution (BSI)

BSI is the national body responsible for preparing British Standards and other standards-related publications, information and services.

BSI is incorporated by Royal Charter. British Standards and other standardization products are published by BSI Standards Limited.

About us

We bring together business, industry, government, consumers, innovators and others to shape their combined experience and expertise into standards -based solutions.

The knowledge embodied in our standards has been carefully assembled in a dependable format and refined through our open consultation process. Organizations of all sizes and across all sectors choose standards to help them achieve their goals.

Information on standards

We can provide you with the knowledge that your organization needs to succeed. Find out more about British Standards by visiting our website at bsigroup.com/standards or contacting our Customer Services team or Knowledge Centre.

Buying standards

You can buy and download PDF versions of BSI publications, including British and adopted European and international standards, through our website at bsigroup.com/shop, where hard copies can also be purchased.

If you need international and foreign standards from other Standards Development Organizations, hard copies can be ordered from our Customer Services team.

Subscriptions

Our range of subscription services are designed to make using standards easier for you. For further information on our subscription products go to bsigroup.com/subscriptions.

With **British Standards Online (BSOL)** you'll have instant access to over 55,000 British and adopted European and international standards from your desktop. It's available 24/7 and is refreshed daily so you'll always be up to date.

You can keep in touch with standards developments and receive substantial discounts on the purchase price of standards, both in single copy and subscription format, by becoming a **BSI Subscribing Member**.

PLUS is an updating service exclusive to BSI Subscribing Members. You will automatically receive the latest hard copy of your standards when they're revised or replaced.

To find out more about becoming a BSI Subscribing Member and the benefits of membership, please visit bsigroup.com/shop.

With a **Multi-User Network Licence (MUNL)** you are able to host standards publications on your intranet. Licences can cover as few or as many users as you wish. With updates supplied as soon as they're available, you can be sure your documentation is current. For further information, email bsmusales@bsigroup.com.

BSI Group Headquarters

389 Chiswick High Road London W4 4AL UK

Revisions

Our British Standards and other publications are updated by amendment or revision.

We continually improve the quality of our products and services to benefit your business. If you find an inaccuracy or ambiguity within a British Standard or other BSI publication please inform the Knowledge Centre.

Copyright

All the data, software and documentation set out in all British Standards and other BSI publications are the property of and copyrighted by BSI, or some person or entity that owns copyright in the information used (such as the international standardization bodies) and has formally licensed such information to BSI for commercial publication and use. Except as permitted under the Copyright, Designs and Patents Act 1988 no extract may be reproduced, stored in a retrieval system or transmitted in any form or by any means – electronic, photocopying, recording or otherwise – without prior written permission from BSI. Details and advice can be obtained from the Copyright & Licensing Department.

Useful Contacts:

Customer Services
Tel: +44 845 086 9001
Email (orders): orders@bsigroup.com
Email (enquiries): cservices@bsigroup.com

Subscriptions
Tel: +44 845 086 9001
Email: subscriptions@bsigroup.com

Knowledge Centre
Tel: +44 20 8996 7004
Email: knowledgecentre@bsigroup.com

Copyright & Licensing
Tel: +44 20 8996 7070
Email: copyright@bsigroup.com

bsi.

...making excellence a habit.™