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Integrated circuits — Measurement of electromagnetic immunity

Part 8: Measurement of radiated immunity — IC stripline method

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National foreword

This British Standard is the UK implementation of EN 62132-8:2012. It is identical to IEC 62132-8:2012.

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

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Integrated circuits - Measurement of electromagnetic immunity - Part 8: Measurement of radiated immunity - IC stripline method (IEC 62132-8:2012)

Circuits intégrés -
Mesure de l'immunité électromagnétique -
Partie 8: Mesure de l'immunité rayonnée -
Méthode de la ligne TEM à plaques pour circuit intégré
(CEI 62132-8:2012)

Integrierte Schaltungen -
Messung der elektromagnetischen Störfestigkeit -
Teil 8: Messung der Störfestigkeit bei Einstrahlungen -
IC-Streifenleiterverfahren
(IEC 62132-8:2012)

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European Committee for Electrotechnical Standardization
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Foreword

The text of document 47A/882/FDIS, future edition 1 of IEC 62132-8, prepared by SC 47A, "Integrated circuits", of IEC TC 47, "Semiconductor devices" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62132-8:2012.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2013-05-10
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2015-08-10

This standard is to be used 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. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62132-8:2012 was approved by CENELEC as a European Standard without any modification.

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. 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	Series	International Electrotechnical Vocabulary	-	-
IEC 61000-4-20	2010	Electromagnetic compatibility (EMC) - Part 4-20: Testing and measurement techniques - Emission and immunity testing in transverse electromagnetic (TEM) waveguides	EN 61000-4-20	2010
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 8: Measurement of radiated immunity – IC stripline method

1 Scope

This part of IEC 62132 specifies a method for measuring the immunity of an integrated circuit (IC) to radio frequency (RF) radiated electromagnetic disturbances over the frequency range of 150 kHz to 3 GHz.

2 Normative references

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

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at http://www.electropedia.org)

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

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

3 Terms and definitions

For the purpose of this document, the terms and definitions given in IEC 62132-1:2006, Clause 3, IEC 60050-131 and IEC 60050-161, and 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

Note 1 to entry: This note only applies to the French language.

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
IC stripline
TEM waveguide, consisting of an active conductor placed on a defined spacing over an enlarged ground plane, connected to a port structure on each end and an optional shielded enclosure

Note 1 to entry: This arrangement guides a wave propagation in the transverse electromagnetic mode to produce a specific field for testing purposes between the active conductor and the enlarged ground plane. The ground plane of the standard EMC test board according to IEC 62132-1:2006, Annex B, should be used. An optional shielding enclosure may be used for fixing the IC stripline configuration and for shielding purposes. This leads to a closed version of the IC stripline in opposite to the open version without shielding enclosure. For further information see Annex A.

3.4
two-port TEM waveguide
TEM waveguide with input/output measurement ports at both ends

3.5
characteristic impedance
magnitude of the ratio of the voltage between the active conductor and the corresponding ground plane to the current on either conductor for any constant phase wave-front

Note 1 to entry: 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. For further information and equation to stripline arrangements see Annex A.

3.6
primary field component
primary component
electric field component aligned with the intended test polarization

Note 1 to entry: For example, in IC stripline, the active conductor is parallel to the horizontal floor, and the primary mode electric field vector is vertical at the transverse centre of the IC stripline.

4 General

An IC to be evaluated for EMC performance is referred to as a device under test (DUT). The DUT should be mounted on an EMC test board according to IEC 62132-1. The EMC test board is provided with the appropriate measurement or monitoring points at which the DUT response parameters can be measured. It controls the geometry and orientation of the DUT relative to the active conductor and eliminates in the case of a closed version of the IC stripline any connecting leads within the housing (these are on the backside of the board, which is outside the housing).

For the IC stripline, one of the 50 Ω ports is terminated with a 50 Ω load. The other 50 Ω port is connected to the output of an RF disturbance generator. The injected RF disturbance signal exposes the DUT to an electromagnetic field determined by the injected power, the typical impedance and the distance between the ground plane of the EMC test board and the active conductor of the IC stripline. The relationship is given in Annex A.

Rotating the EMC test board in the four possible orientations in the aperture to accept EMC test board of the IC stripline will affect the sensitivity of the DUT. 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). The intent of this test method is to provide a quantitative measure of the RF immunity of DUTs for comparison or other purposes.

For further information see Annex A.

5 Test conditions

5.1 General

The test conditions shall meet the requirements as described in IEC 62132-1:2006, Clause 4. In addition, the following test conditions shall apply.

5.2 Supply voltage

The supply voltage shall be as specified by the IC manufacturer. If the users of this procedure agree to other values, they shall be documented in the test report.

5.3 Frequency range

The effective frequency range of this radiated immunity procedure is 150 kHz to 3 GHz.

6 Test equipment

6.1 General

The test equipment shall meet the requirements described in IEC 62132-1:2006, Clause 5. 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 ambient conditions.

6.3 Shielding

Testing in a shielded room is only necessary for the open IC stripline version. The closed version of the IC stripline is shielded by its housing.

6.4 RF disturbance generator

An RF disturbance generator with sufficient power handling capabilities shall be used. The RF disturbance generator may comprise an RF signal source with a modulation function, an RF power amplifier. The voltage standing wave ratio (VSWR) at the output of the RF disturbance generator shall be less than 1,5 over the frequency range being measured.

The gain (or attenuation) of the RF disturbance generating equipment, without the IC stripline, shall be known with an accuracy ±0,5 dB.

6.5 IC stripline

The IC stripline (open or closed version) used for this test procedure shall be fitted with an aperture to mate with the EMC test board. The IC stripline shall not exhibit higher order modes over the frequency range being measured. For this procedure, the IC stripline frequency range is 150 kHz to 3 GHz. The VSWR over the frequency range of the empty IC stripline being measured shall be less than 1,25.

For further information as to field strength determination, IC stripline designs and the limitation of geometrical dimensions of closed version, see Annexes A, B and C.

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 recommended for the IC stripline 50 Ω 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 setup

7.1 General

A test setup shall meet the requirements described in IEC 62132-1:2006, Clause 6. In addition, the following test setup requirements shall apply.

7.2 Test configuration

See Figure 1 for IC stripline test configurations. One of the IC stripline 50 Ω ports is terminated with a 50 Ω load. The other IC stripline 50 Ω port is connected to the output port of the RF disturbance generator.

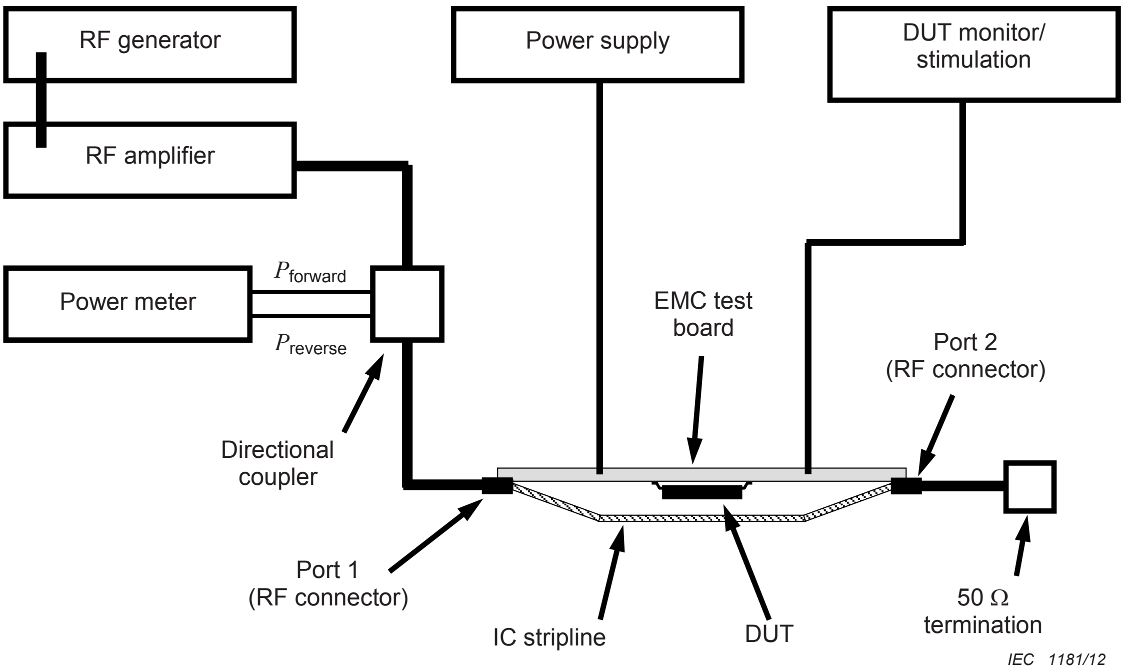


Figure 1 – IC stripline test setup

For further information and cross section view of IC stripline see Annex B.

7.3 EMC test board (PCB)

The EMC test board shall be designed in accordance with the requirements in IEC 62132-1.

8 Test procedure

8.1 General

Test procedure shall be in accordance with IEC 62132-1:2006, Clause 7, except as modified herein. These default test conditions are intended to assure a consistent test environment. The following steps shall be performed:

a) Operational check (see 8.2)

b) Immunity measurement (see 8.3)

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

8.2 Operational check

Energize the DUT and complete an operational check to verify proper function of the device (i.e. run DUT test code) in the ambient test condition. During the operational check, the RF disturbance generator and any monitoring equipment shall be powered; however, the output of the RF disturbance generator shall be disabled. The performance of the DUT shall not be degraded by ambient conditions.

8.3 Immunity measurement

8.3.1 General

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

8.3.2 RF disturbance signal

The RF disturbance signal may be:

- CW (continuous wave, no modulation)
- sinusoidal modulated with 80 % amplitude modulated by a 1 kHz sine wave, and
- pulse modulated with 50 % duty cycle and 1 kHz pulse repetition rate.

8.3.3 Test frequency steps and ranges

The RF immunity of the DUT is generally evaluated in the frequency range from 150 kHz to 3 GHz. The frequencies to be tested shall be generated from the requirements specified in Table 1.

Table 1 – Frequency step size versus frequency range

Frequency range (MHz)	0,15 – 1	1 – 100	100 – 1000	1000-3000
Linear steps (MHz)	≤0,1	≤1	≤10	≤20
Logarithmic steps	≤5 % increment			

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.

8.3.4 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 (test level) is reached. The step size and test level shall be documented in the test report.

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

8.3.5 DUT monitoring

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

8.3.6 Detail procedure

8.3.6.1 Field strength determination

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.

8.3.6.2 Immunity measurement

The test flow, including major steps, is described below. One of two strategies can 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 a desired upper 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. This level shall also be recorded.

NOTE The DUT can 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 can be required. Additionally, in some cases, it might be necessary to reset or restart the DUT to come back to proper operation.

The RF immunity measurement shall be performed for at least two orientations (0°, 90°). If necessary the other orientations 180° and 270° should be tested too. The first measurement is made with the EMC test board mounted in an arbitrary orientation in the IC stripline aperture to accept EMC test board. The second measurement is made with the EMC test board rotated 90 degrees from the orientation in the first measurement. For each of the third and fourth measurements, the EMC test board is rotated again to ensure immunity is measured in all four possible orientations. The results and their tested orientations shall be documented in the test report.

9 Test report

The test report shall be in accordance with the requirements of IEC 62132-1:2006, Clause 8.

10 RF immunity acceptance level

The RF immunity acceptance level of a DUT, if any, is to be agreed upon between the manufacturer and the user of the DUT and can be defined also differently for special frequency bands.

Annex A
(normative)

Field strength determination

A.1 General

The signal level setting of the RF disturbance generator required to achieve the desired electric field level within the IC stripline 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 specified in 8.3.1. The RF disturbance signal shall be a CW signal (i.e. no modulation shall be applied).

A.2 Characteristic impedance of stripline arrangements

The nominal, characteristic impedance of an open version of IC stripline can be calculated as follows [3], if $1 < w/h \leq 10$

$$Z = \frac{120 \times \pi}{\frac{w}{h} + 2{,}42 - 0{,}44 \times \frac{h}{w} + \left[1 - \frac{h}{w}\right]^6} \qquad \text{(A.1)}$$

Where

Z = characteristic impedance [Ω], typically 50 Ω

w = width [m] of active conductor (see Figure A.1)

h = height [m] between surfaces of the active conductor and ground plane (see Figure A.1)

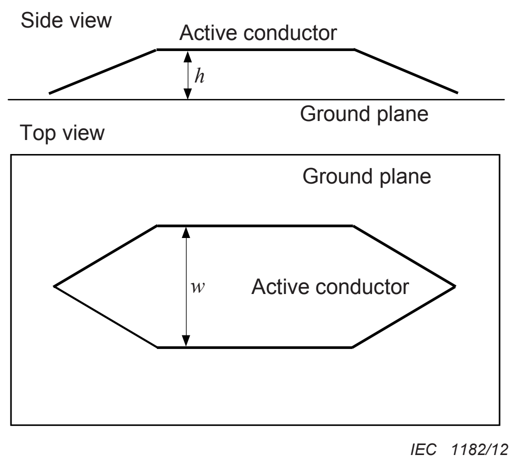


Figure A.1 – Definition of height *(h)* and width *(w)* of IC stripline

For the closed version of the IC stripline the influence of housing has to be taken into account. This correction depends on the housing geometry. For spherical housing surface an analytical formula for the characteristic impedance cannot be provided, empirical investigations are necessary. The characteristic impedance of those stripline arrangements have to be verified by measurement.

A.3 Field strength calculation

The RF disturbance applied at the input to the IC stripline is related to the electromagnetic field by the distance between the active conductor and the ground plane of the EMC test board.

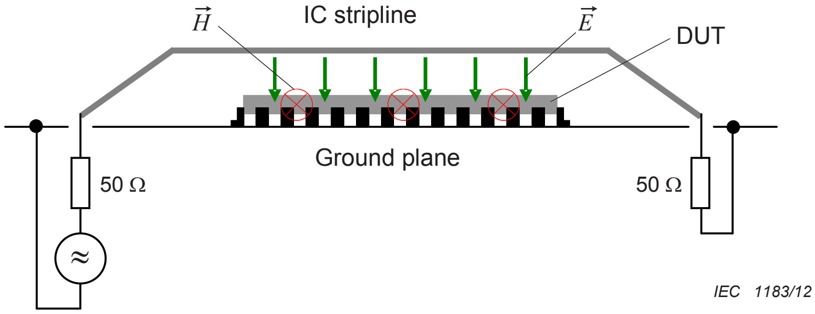


Figure A.2 – EM field distribution

$$E = \frac{\sqrt{P \times Z}}{h} \quad \text{(A.2)}$$

Where

- E = electric field strength [V/m] within the IC stripline
- Z = characteristic impedance [Ω], nominal value
- P = measured forward test power [W]
- h = height [m] between the surfaces of active conductor and ground plane of the EMC test board

Tests with closed and open version of IC stripline, both with an impedance of 50 Ω, have shown that slightly different coupling between IC stripline versions and DUT appears. The deviation is in the range of approximately 0,5 dB to 1 dB [4]. In practice, this offset can be neglected for proposed geometrical dimensions of the IC stripline as given in Annex B. For any other geometrical dimension, the active conductor width of closed version shall not be less than 70% of the width of the referring open version as described in Annex C.

A.4 Verification of IC stripline RF characteristic

For verification of the IC stripline RF characteristic, the VSWR value of the empty IC stripline with 50 Ω load termination at the second port shall be measured and documented in the test report. The value shall be lower than 1,25.

In addition, it is recommended to check also the DUT loaded IC stripline. In accordance to IEC 61000-4-20, IC stripline resonances with DUT shall be considered, with DUT power off.

$$A_{\text{tloss}} = \left| 10 \times \log\left(\frac{P_{\text{refl}}}{P_{\text{fwd}}} + \frac{P_{\text{output}}}{P_{\text{fwd}}} \right) \right| \leq 1\,\text{dB} \quad \text{(A.3)}$$

Where

- A_{tloss} = Transmission loss of loaded IC stripline [dB]

P_{refl} = reflected power at input port [W]

P_{fwd} = forward power at input port [W]

P_{output} = measured power at output port [W]

Measurements carried out at frequencies where the VSWR and losses exceed the maximum tolerated values shall be ignored.

Annex B
(normative)

IC stripline descriptions

B.1 IC stripline

The IC stripline offers a broadband method of measuring either immunity of a DUT to fields generated within the IC stripline or radiated emission from a DUT placed within the IC stripline. It eliminates the use of conventional antennas with their inherent measurement limitations of bandwidth, non-linear phase, directivity and polarization. The IC stripline is a special kind of transmission line that propagates a TEM wave. This wave is characterized by transverse orthogonal electric (E) and magnetic (H) fields, which are perpendicular to the direction of propagation along the length of the IC stripline 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 IC stripline 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 IC stripline to generate or detect a field intensity in a defined way. The upper useful frequency for an IC stripline is limited by distortion of the test signal caused by resonances and multi-moding that occur within the IC stripline. These effects are a function of the physical size and shape of the IC stripline.

The IC stripline is of a size and shape, with impedance matching at the input and output feed points of the IC stripline that limits the VSWR to less than 1,25 up to its rated frequency. In principle there are two versions of IC stripline possible – open and closed version. The open version uses the common stripline configuration (Figure B.1). At the closed version a shielding case is added (Figure B.2). To get the same characteristic impedance for the closed version as the one for the open version with the same height of active conductor, the width needs to be reduced to keep the 50 Ω characteristic impedance. The correct width value depends on the shape of the housing. As long as the 50 Ω characteristic impedance is kept for both versions the electric field strength conditions can be calculated by Equation A.2 and corrected if necessary as described in Annex C.

The active conductor of the IC stripline is tapered at each end to adapt to conventional 50 Ω coaxial connectors. The requested EMC test board can be based on a TEM cell board according to IEC 62132-1. The first resonance is demonstrated by a high VSWR over a narrow frequency range. An IC stripline verified for field generation to a maximum frequency will also be suitable for emission measurements to this frequency.

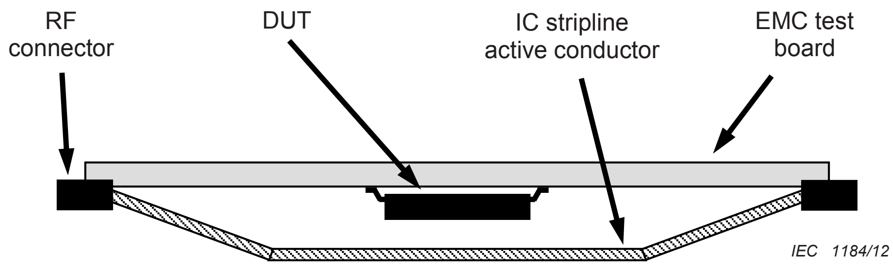


Figure B.1 – Cross section view of an example of an open IC stripline

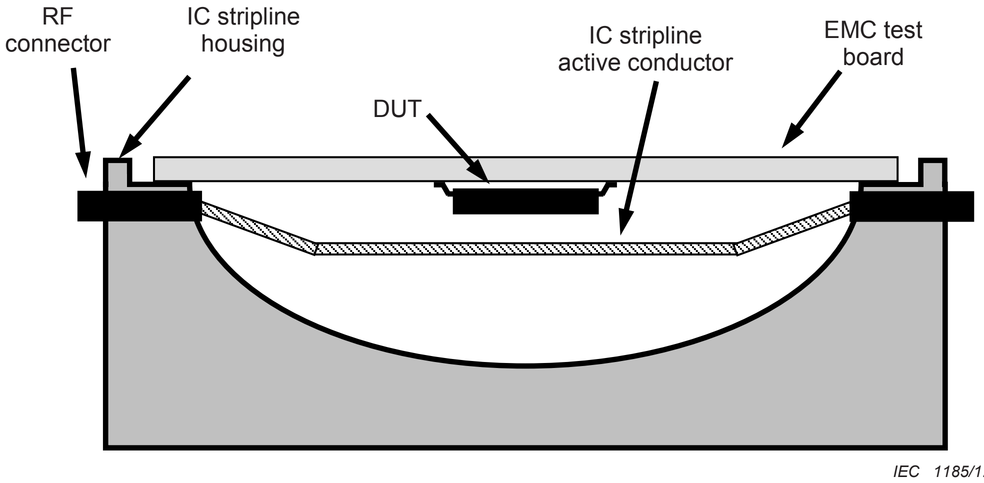


Figure B.2 – Cross section view of an example of a closed IC stripline

The maximum usable DUT size is limited by the IC stripline dimensions. The ratio of DUT package height to IC stripline height is recommended to one third but shall not exceed one half according to IEC 61000-4-20. In x-y dimension the package shall not exceed the width of active conductor by more than 10 %.

NOTE 3 D field simulations of a IC stripline setup with a DUT, whose package size exceeds the width of the active conductor by 10 % at a half of active conductor height, have shown that a uniform field (not more than +0 dB and not less than -3 dB) is still present at the DUT beyond the active conductor edge [4].

The limitation values for the 6,7 mm IC stripline for example are given in Tables B.1 and B.2.

Table B.1 – Maximum DUT dimensions for 6,7 mm IC stripline (Open version)

	Active conductor 6,7 mm IC stripline open version	**DUT**
z dimension (height)	6,7 mm	≤3,35 mm
x-y dimension (width)	33 mm	≤36,3 mm

Table B.2 – Maximum DUT dimensions for 6,7 mm IC stripline (Closed version)

	Active conductor 6,7 mm IC stripline closed version	**DUT**
z dimension (height)	6,7 mm	≤3,35 mm
x-y dimension (width)	24 mm	≤26,4 mm

B.2 Example for IC stripline arrangement

An example for IC stripline with housing is given in Figure B.3. The housing x-y dimensions are defined by the used EMC test board (IEC 62132-1: 100 mm × 100 mm). The housing in z direction should be as far as possible from the active conductor but avoid resonances and multi-moding in the frequency range of interest.

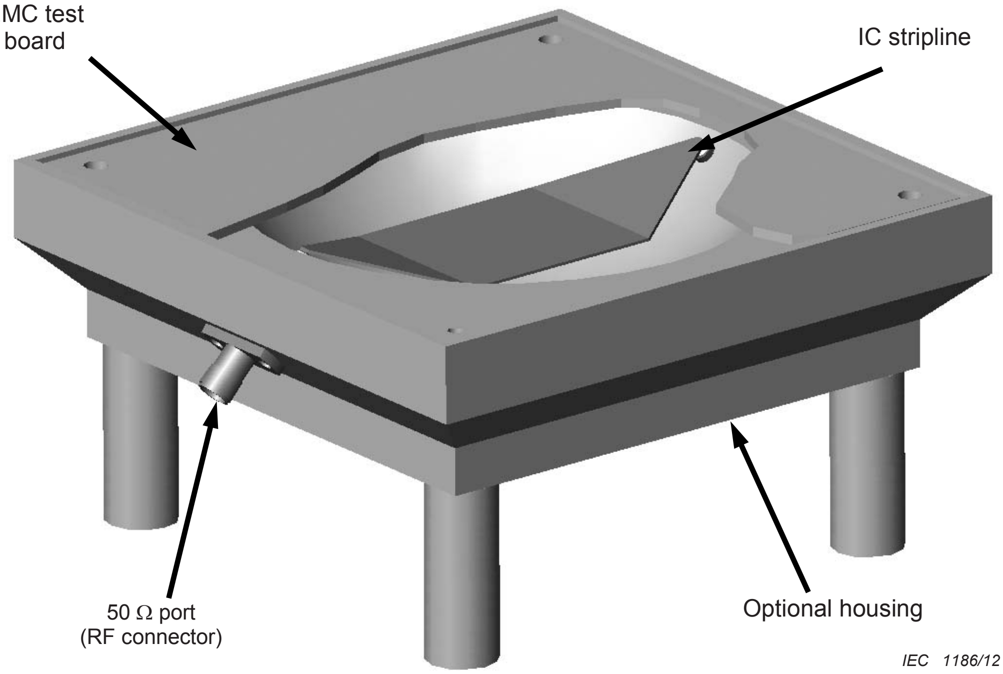


Figure B.3 – Example of IC stripline with housing

Annex C
(informative)

Closed stripline geometrical limitations

An open version of IC stripline with any conductor height is designed to realize a characteristic wave impedance of $Z = 50\ \Omega$. By adding a shielding, an additional partial stripline capacitance arises and therefore the width of the active conductor has to be reduced to keep impedance $Z = 50\ \Omega$. This reduction of the width of the active conductor is limited in order to achieve comparable field levels in open and closed version of IC stripline. As distance of shielding is controlled by the reduction of the width of the active conductor and the geometrical shape of shielding, the distance of shielding is limited accordingly.

In the case of open version of IC stripline, only one grounded plane parallel to active conductor is used. Back current occurs in this plane. In the case of referring closed version, second grounded plane is added (shielding). Back current occurs in both planes, fractions depend on chosen geometries.

H-fields at location of DUT are superposed. In the case of open version they are generated by current flow located in active conductor (quasi-static approach) and due to mirrored current at grounded bottom plane. In the case of referring closed version, mirroring has to be done at grounded bottom and shielding planes, resulting in a convergent infinite series of H-fields [5]. Compare Figure C.2 and Formula (C.2). Reducing width of active conductor results in increasing levels of current density and therewith increasing H-field at location of DUT in the case of considering only field generated by current at the location of the active conductor. Coexistent, H-field level at location of DUT is overally reduced due to superposing effects of mirrored currents as second grounded plane above active conductor is added. Effects eliminate each other approximately in the case of limited geometrical setups with a limitation of active conductor width. To achieve negligible field differences of setups, active conductor width of closed version should not be reduced to less than approximate 70% of referring open version as shown below. As impedance $Z = 50\ \Omega$ has to be achieved, this yields accordingly in limitation of usable heights of shielding. Values of heights of shielding are depending on used geometrical shape of shielding. Shifting shielding very close to active conductor (referring to highly reducing width of active conductor) and keeping distance of active conductor to DUT constant would result in high fraction of back current in shielding. Distance of active conductor to DUT is far greater than to shielding. Therewith, H-fields at location of DUT would largely cancel each other and different field behaviour would be achieved compared to the open version of IC stripline.

H-field generated by current at active conductor as band conductor at distance of DUT which is located centrically close to bottom plane is calculated from Formula (C.1). H-fields of mirrored currents are calculated accordingly and superposed. In the case of the closed version, convergent infinite series result. See Formula (C.2).

$$\left|H_{\text{septum},\text{DUT}}\right| = \frac{|J| \times t}{\pi} \operatorname{arcsinh}\left(\frac{w/2}{a}\right) \tag{C.1}$$

Where

J = current density

t = active conductor thickness

w = active conductor width

a = perpendicular distance of active conductor to centrically placed DUT

$$|H| = |H_{single}(J)| \Bigg[\operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} - x}\right) + \operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} + x}\right) - \operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} - x + 2 \times h_{shielding}}\right) - \operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} + x + 2 \times h_{shielding}}\right) + \operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} - x + 2 \times h_{shielding} + 2 \times h_{bottom}}\right) + \operatorname{arcsinh}\left(\frac{w/2}{h_{bottom} + x + 2 \times h_{shielding} + 2 \times h_{bottom}}\right) - \ldots + \ldots \Bigg] \quad \text{(C.2)}$$

Where

J =	current density
w =	active conductor width
h_{bottom}, $h_{shielding}$ =	perpendicular distance of active conductor to bottom/ shielding
x =	distance of centrically placed DUT to bottom

Current distribution is assumed to be homogeneous; therewith density J increases by w_{open}/w_{closed} in the case of reducing width of active conductor.

Resulting H-field of closed version at location of DUT is referenced to resulting H-field of referring open version of IC stripline. In the following, active conductor height of $h_{bottom} = 6{,}7$ mm is regarded. Active conductor width is reduced to fractions of width of referring open version. Referring height of shielding $h_{shielding}$ to achieve impedance Z = 50 Ω is assumed by formula given in (C.3).

$$h_{shielding} = h_{fit} \times \frac{w_{closed}/w_{open}}{(1 - w_{closed}/w_{open})} \times h_{bottom}, \text{ with } h_{fit} = \frac{38}{35} - \frac{3}{7} \times w_{closed}/w_{open} \quad \text{(C.3)}$$

Where

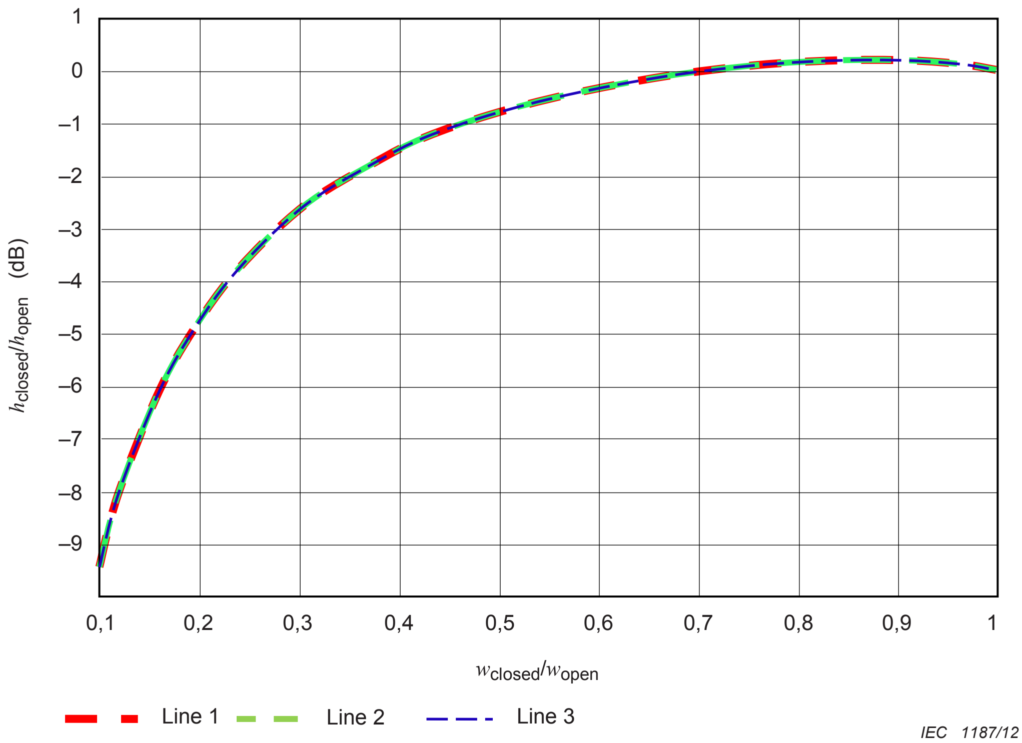
$h_{shielding}$, h_{bottom}	as defined in Figure C.2
w_{closed} =	active conductor width of closed version
w_{open} =	active conductor width of referring open version

This approximation Formula (C.3) is based on some spot tests of simulation of an IC stripline with spherically shaped shielding. Some shielding heights are calculated to achieve 50 Ω in impedance and shown in Table C.1 as a function of w_{closed}/w_{open}.

Table C.1 – Height of shielding, simulated at h_{bottom} = 6,7mm to achieve practically 50 Ω system

w_{closed}/w_{open}; $w_{open} = 33$ mm	$h_{shielding}$
0,2	1,68 mm
0,4	4,0 mm
0,6	8,5 mm
0,73	14,5 mm
0,8	19,5 mm
0,9	41 mm

Resulting calculated *H*-field reduction of the closed version compared to the referring open version is shown in Figure C.1. By this calculation, a negligible increase of *H*-field would be expected in the case of slight reduction of active conductor width, independent of starting width of referring open version (50 Ω system). Further decrease of active conductor width results in decreasing $h_{\text{shielding}}$ and finally in decreasing *H*-field at location of DUT. Realized setup with active conductor heights 6,7 mm refers to an active conductor width reduction to 73% (24 mm for closed version derived from 33 mm active conductor width of open version). At this value, experimental result is an overall coupling reduction of approximately 0,5 dB in comparison to referring open version. As shown in Figure C.1, decreasing active conductor width further would be expected to lead to higher coupling reductions in the case of *H*-field coupling. To keep universality, active conductor width of closed version shall not be reduced to lower values than approximately 70% of referring version. Therewith, shielding shall keep minimum distance to active conductor in order to achieve impedance $Z = 50\ \Omega$, value of $h_{\text{shielding}}$ depends on chosen geometrical shape of shielding.



Key

Line 1 w_{open} = 10 mm,

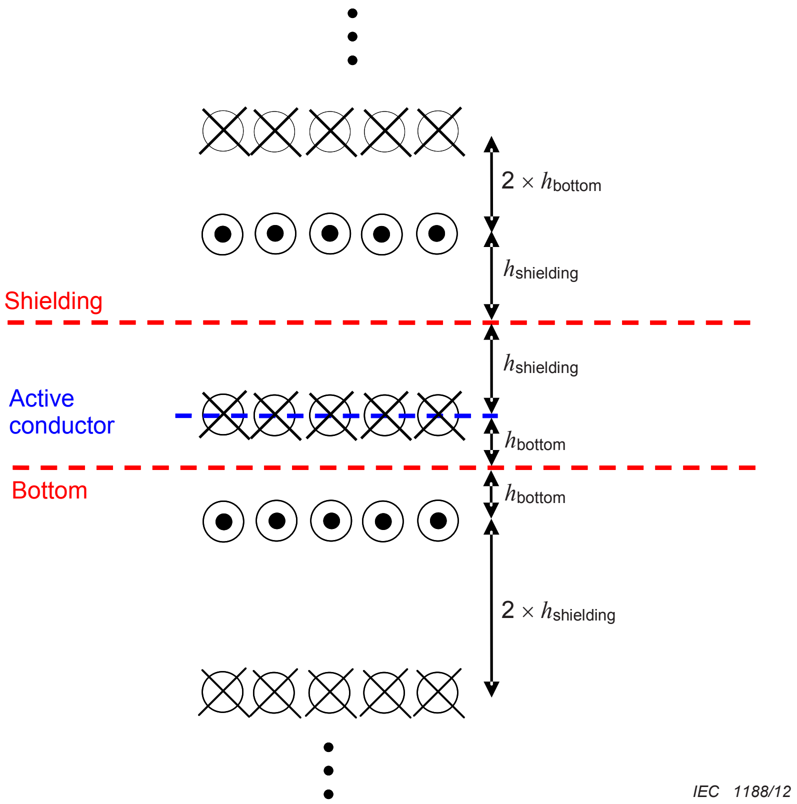
Line 2 w_{open} = 100 mm,

Line 3 w_{open} = 33 mm

(Line 3 experimental setup; all 50 Ω systems; all lines on top of each other).

Figure C.1 – Calculated *H*-field reduction of closed version referenced to referring open version as a function of portion of active conductor width of closed version to open version

Experimental setups (active conductor width reduction of 73 %) yields approximately 0,5 dB to 1 dB reduced coupling and therewith rather slightly more *H*-field reduction as calculated. This might be due to the fixed shielding height, shielding is approximated as a grounded parallel plate in calculation instead of shaped geometry and/or slightly higher portion of current could be located at shielding due to geometrical shapes and due to the fact that adapters to IC stripline are connected to shielding body. This would yield to slightly less H-field at the location of DUT than the one ideally calculated.



Key

h_{bottom} = perpendicular distance of active conductor to bottom

$h_{shielding}$ = perpendicular distance of active conductor to shielding

Figure C.2 – Location of currents and mirrored currents at grounded planes used for calculation of fields

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