มาตรฐานผลิตภัณฑ์อุตสาหกรรม

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CISPR 16–2–4(2003–11)

ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน

เล่ม 2–4 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน – การวัดภูมิคุ้มกัน

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS–

PART 2–4 : METHODS OF MEASUREMENT OF DISTURBANCES AND IMMUNITY – IMMUNITY MEASUREMENTS

สำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

กระทรวงอุตสาหกรรม

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บริภัณฑ์ไฟฟ้าและอิเล็กทรอนิกส์ ตลอดจนบริภัณฑ์เทคโนโลยีสารสนเทศในขณะใช้งานจะต้องไม่ส่งสัญญาณรบกวนเข้าสู่ระบบไฟฟ้าหรือรบกวนการทำงานของบริภัณฑ์ข้างเคียง รวมทั้งตัวบริภัณฑ์เองก็ต้องมีภูมิคุ้มกันในระดับเพียงพอที่จะทำงานในสภาวะแวดล้อมทางแม่เหล็กไฟฟ้าในระดับหนึ่งได้ จึงกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-4 วิธีการวัดของสัญญาณรบกวน และภูมิคุ้มกัน-การวัดภูมิคุ้มกัน ขึ้น

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นโดยรับ CISPR 16-2-4(2003-11) Specification for radio disturbance and immunity measuring apparatus and methods - Part 2-4 : Methods of measurement of disturbances and immunity - Immunity measurements มาใช้ในระดับเหมือนกันทุกประการ(identical) โดยใช้ CISPR ฉบับภาษาอังกฤษเป็นหลัก

มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้กำหนดขึ้นเพื่อใช้ในการอ้างอิง และเพื่อให้ทันกับความต้องการของผู้ใช้มาตรฐาน ซึ่งจะได้แปลเป็นภาษาไทยในโอกาสอันสมควรต่อไป หากมีข้อสงสัยโปรดติดต่อสอบถามสำนักงานมาตรฐานผลิตภัณฑ์อุตสาหกรรม

คณะกรรมการมาตรฐานผลิตภัณฑ์อุตสาหกรรมได้พิจารณามาตรฐานนี้แล้ว เห็นสมควรเสนอรัฐมนตรีประกาศตามมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. 2511

ประกาศกระทรวงอุตสาหกรรม

ฉบับที่ 3499 (พ.ศ. 2549)

ออกตามความในพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม

พ.ศ. 2511

เรื่อง กำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม

ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน

เล่ม 2-4 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน -

การวัดภูมิคุ้มกัน

อาศัยอำนาจตามความในมาตรา 15 แห่งพระราชบัญญัติมาตรฐานผลิตภัณฑ์อุตสาหกรรม พ.ศ. 2511 รัฐมนตรีว่าการกระทรวงอุตสาหกรรมออกประกาศกำหนดมาตรฐานผลิตภัณฑ์อุตสาหกรรม ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน เล่ม 2-4 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดภูมิคุ้มกัน มาตรฐานเลขที่ มอก. 2092 เล่ม 4-2549 ไว้ ดังมีรายละเอียดต่อท้ายประกาศนี้

ประกาศ ณ วันที่ 4 พฤษภาคม พ.ศ. 2549

สุริยะ จึงรุ่งเรืองกิจ

รัฐมนตรีว่าการกระทรวงอุตสาหกรรม

มาตรฐานผลิตภัณฑ์อุตสาหกรรม
ข้อกำหนดสำหรับอุปกรณ์และวิธีการวัดสัญญาณรบกวนวิทยุและภูมิคุ้มกัน
เล่ม 2-4 วิธีการวัดของสัญญาณรบกวนและภูมิคุ้มกัน - การวัดภูมิคุ้มกัน

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มาตรฐานผลิตภัณฑ์อุตสาหกรรมนี้ได้รับการระบุให้เป็นมาตรฐานพื้นฐาน ซึ่งกำหนดวิธีการวัดภูมิคุ้มกันต่อปรากฏการณ์ความเข้ากันได้ทางแม่เหล็กไฟฟ้า ในพิสัยความถี่ 9 กิโลเฮิรตซ์ ถึง 18 จิกะเฮิรตซ์

รายละเอียดให้เป็นไปตาม CISPR 16-2-4 (2003-11)

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INTERNATIONAL ELECTROTECHNICAL COMMISSION
INTERNATIONAL SPECIAL COMMITTEE ON RADIO INTERFERENCE

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

International Standard CISPR 16-2-4 has been prepared by CISPR subcommittee A: Radio interference measurements and statistical methods.

This first edition of CISPR 16-2-4, together with CISPR 16-2-1, CISPR 16-2-2 and CISPR 16-2-3, cancels and replaces the second edition of CISPR 16-2, published in 2003. It contains the relevant clauses of CISPR 16-2 without technical changes.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until 2006. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

INTRODUCTION

CISPR 16-1, CISPR 16-2, CISPR 16-3 and CISPR 16-4 have been reorganised into 14 parts, to accommodate growth and easier maintenance. The new parts have also been renumbered. See the list given below.

Old CISPR 16 publications

CISPR 16-1	Radio disturbance and immunity measuring apparatus
CISPR 16-2	Methods of measurement of disturbances and immunity
CISPR 16-3	Reports and recommendations of CISPR
CISPR 16-4	Uncertainty in EMC measurements

New CISPR 16 publications

CISPR 16-1-1	Measuring apparatus
CISPR 16-1-2	Ancillary equipment – Conducted disturbances
CISPR 16-1-3	Ancillary equipment – Disturbance power
CISPR 16-1-4	Ancillary equipment – Radiated disturbances
CISPR 16-1-5	Antenna calibration test sites for 30 MHz to 1 000 MHz
CISPR 16-2-1	Conducted disturbance measurements
CISPR 16-2-2	Measurement of disturbance power
CISPR 16-2-3	Radiated disturbance measurements
CISPR 16-2-4	Immunity measurements
CISPR 16-3	CISPR technical reports
CISPR 16-4-1	Uncertainties in standardised EMC tests
CISPR 16-4-2	Measurement instrumentation uncertainty
CISPR 16-4-3	Statistical considerations in the determination of EMC compliance of mass-produced products
CISPR 16-4-4	Statistics of complaints and a model for the calculation of limits

More specific information on the relation between the 'old' CISPR 16-2 and the present 'new' CISPR 16-2-4 is given in the table after this introduction (TABLE RECAPITULATING CROSS REFERENCES).

Measurement instrumentation specifications are given in five new parts of CISPR 16-1, while the methods of measurement are covered now in four new parts of CISPR 16-2. Various reports with further information and background on CISPR and radio disturbances in general are given in CISPR 16-3. CISPR 16-4 contains information related to uncertainties, statistics and limit modelling.

CISPR 16-2 consists of the following parts, under the general title *Specification for radio disturbance and immunity measuring apparatus and methods – Methods of measurement of disturbances and immunity:*

- Part 2-1: Conducted disturbance measurements,
- Part 2-2: Measurement of disturbance power,
- Part 2-3: Radiated disturbance measurements,
- Part 2-4: Immunity measurements.

TABLE RECAPITULATING CROSS-REFERENCES

Second edition of CISPR 16-2 Clauses, subclauses	First edition of CISPR 16-2-4 Clauses, subclauses
1.1	1
1.2	2
1.3	3
3.1	4
3.2	5
3.3	6
Figures	Figures
25, ... 31	1, ... 7

SPECIFICATION FOR RADIO DISTURBANCE AND IMMUNITY MEASURING APPARATUS AND METHODS –

Part 2-4: Methods of measurement of disturbances and immunity – Immunity measurements

1 Scope

This part of CISPR 16 is designated a basic standard, which specifies the methods of measurement of immunity to EMC phenomena in the frequency range 9 kHz to 18 GHz.

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 60083:1997, *Plugs and socket-outlets for domestic and similar general use standardized in member countries of IEC*

IEC 60364-4: *Electrical installations of buildings – Part 4: Protection for safety*

CISPR 16-1-2:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-2: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Conducted disturbances*

CISPR 16-1-4:2003, *Specification for radio disturbance and immunity measuring apparatus and methods – Part 1-4: Radio disturbance and immunity measuring apparatus – Ancillary equipment – Radiated disturbances*

ITU-R Recommendation BS.468-4: *Measurement of audio-frequency noise voltage level in sound broadcasting*

3 Definitions

For the purpose of this part of CISPR 16, the definitions of IEC 60050(161) apply, as well as the following:

3.1
associated equipment

1) Transducers (e.g. probes, networks and antennas) connected to a measuring receiver or test generator
2) Transducers (e.g. probes, networks, antennas) which are used in the signal or disturbance transfer between an EUT and measuring equipment or a (test-) signal generator

3.2
EUT
the equipment (devices, appliances and systems) subjected to EMC (emission and immunity) compliance tests

3.3
product publication
publication specifying EMC requirements for a product or product family, taking into account specific aspects of such a product or product family

3.4
immunity limit
the specified minimum immunity level

[IEV 161-03-15]

3.5
ground reference
a connection that constitutes a defined parasitic capacitance to the surrounding of an EUT and serves as reference potential

NOTE See also IEV 161-04-36.

3.6
(electromagnetic) emission
the phenomenon by which electromagnetic energy emanates from a source

[IEV 161-01-08]

3.7
coaxial cable
a cable containing one or more coaxial lines, typically used for a matched connection of associated equipment to the measuring equipment or (test-)signal generator providing a specified characteristic impedance and a specified maximum allowable cable transfer impedance

3.8
common mode (asymmetrical disturbance voltage)
the RF voltage between the artificial midpoint of a two-conductor line and reference ground, or in case of a bundle of lines, the effective RF disturbance voltage of the whole bundle (vector sum of the unsymmetrical voltages) against the reference ground measured with a clamp (current transformer) at a defined terminating impedance

NOTE See also IEV 161-04-09.

3.9
common mode current
the vector sum of the currents flowing through two or more conductors at a specified cross-section of a "mathematical" plane intersected by these conductors

3.10
differential mode voltage; symmetrical voltage
the RF disturbance voltage between the wires of a two conductor line

[IEV 161-04-08, modified]

3.11
differential mode current
half the vector difference of the currents flowing in any two of a specified set of active conductors at a specified cross-section of a "mathematical" plane intersected by these conductors

3.12
unsymmetrical mode (V-terminal voltage)
the voltage between a conductor or terminal of a device, equipment or system and a specified ground reference. For the case of a two-port network, the two unsymmetrical voltages are given by:

a) the vector sum of the asymmetrical voltage and half of the symmetrical voltage; and

b) the vector difference between the asymmetrical voltage and half of the symmetrical voltage.

NOTE See also IEV 161-04-13.

3.13
test configuration
gives the specified measurement arrangement of the EUT in which an emission or immunity level is measured

NOTE The emission level or immunity level is measured as required by IEV 161-03-11, IEV 161-03-12, IEV 161-03-14 and IEV 161-03-15, definitions of emission level and immunity level.

3.14
artificial network (AN)
an agreed reference load (simulation) impedance presented to the EUT by actual networks (e.g., extended power or communication lines) across which the RF disturbance voltage is measured

3.15
fully anechoic chamber (FAC) or fully anechoic room (FAR)
shielded enclosure, the internal surfaces of which are lined with radio frequency absorbing material (i.e. RAM), that absorbs electromagnetic energy in the frequency range of interest. The Fully Absorber-Lined Room is intended to simulate a free space environment where only the direct ray from the transmitting antenna reaches the receiving antenna. All indirect and reflected waves are minimised with the use of proper absorbing material on all walls, the ceiling and the floor of the FAR

4 Immunity test criteria and general measurement procedures

Immunity measurements are based upon a judgment of the point when the effect of interference on the EUT (equipment under test) has reached a specified level.

Immunity measurements are performed in general by the application of a wanted test signal and an unwanted signal to the EUT. The fundamental basis of the measurement is set out in this clause, together with a listing of conditions which need to be specified in the detailed recommendations produced by the CISPR product committees. Clause 5 deals with the general principals of conduction methods of measurement for immunity, and clause 6 with radiation methods.

4.1 General measurement method

Figure 1 sets out the fundamental concept upon which all methods of measurement of immunity are based.

The EUT is set up as specified to represent normal operating conditions. The unwanted signal is applied with increasing severity until the prescribed performance degradation is detected or the specified immunity level is reached, whichever is lower.

The unwanted signal may be introduced by direct radiation or by current/voltage injection. In most cases both the direct radiation and injection techniques will be needed to fully assess the immunity potential of EUTs. The injection method is most useful for frequencies under 150 MHz, although direct radiated tests above approximately 30 MHz are used. The direct radiated tests can be performed using fields launched by antennas and intercepted by the EUT. In some cases a "bounded" field is most efficient for EUTs of height less than 1 m. Examples of bounded fields occur with TEM cells, stripline antennas and mode-stirred enclosures.

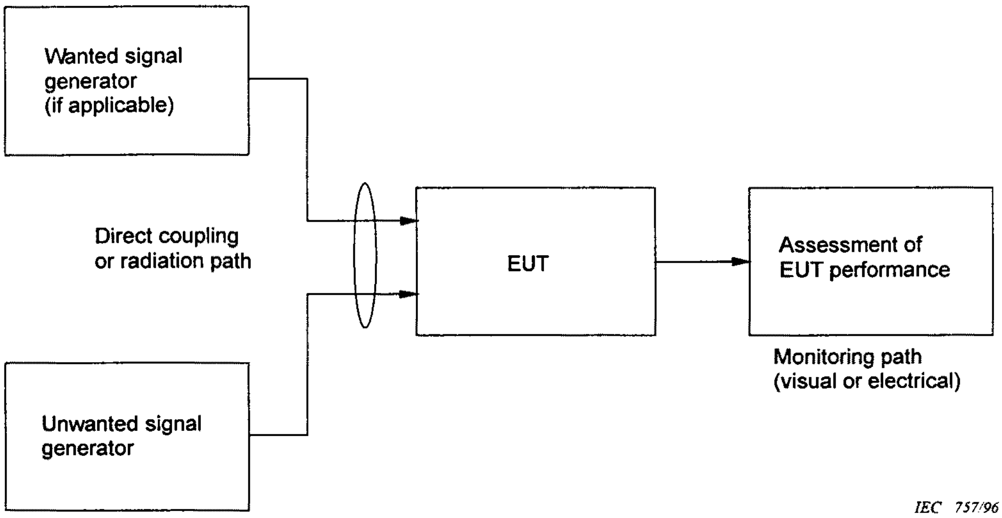


Figure 1 – Fundamental concept of immunity measurement

4.1.1 Objective assessment of performance degradation

Objective assessment of EUT immunity is made by monitoring voltages, currents, specific signals, audio rectification levels, etc., which can be recorded using analogue or digital recording techniques.

As an example of one such assessment of performance degradation, the immunity of television receivers to AM modulated RF interference is presented below.

First the wanted test signal only is applied to the EUT. This produces a wanted audio signal which is measured. The control of the EUT or test set-up is adjusted to set this audio signal at the required level. The wanted audio signal is then removed either by switching off the modulation or the audio test signal. The unwanted signal is applied in addition and its level is adjusted to obtain an unwanted audio signal at the specified level below the wanted audio signal level. The level of the unwanted signal is the measure of immunity of the EUT at the test frequency concerned. Care should be taken in order not to damage the EUT by too high levels of the unwanted signal.

4.1.2 Subjective assessment of performance degradation

Subjective assessment of EUT immunity is made by visual and/or aural monitoring of performance degradation for EUTs with such visual or aural or both presentations. This technique differs from that in 4.1.1 in that specific electrical or similar signals and levels are not directly recorded with an analogue or digital format. Instead, performance degradation is not formulated in measurable terms but in human sensory terms, e.g., human audio or visual perception of an annoying effect. The unwanted immunity signals can be the same or similar to those used for objective immunity assessment measurements.

As an example of one such subjective assessment of performance degradation, the immunity of television receivers to an unwanted signal, as perceived by humans as degraded visual and aural presentations, is given below.

In the case of picture interference, the wanted test signal produces a standard picture and the unwanted signal produces a degradation of the picture. The degradation may be in a number of forms, such as a superposed pattern, sync disturbance, geometrical distortion, loss of picture contrast or colour, etc.

The criterion of what constitutes performance degradation needs to be prescribed, and the conditions under which the subjective assessment is to be made must be specified.

First the wanted signal only is applied to the EUT. The controls of the EUT are set to obtain a picture of normal brightness, contrast and colour saturation. The unwanted signal is then applied in addition and its level adjusted to obtain degradation of the picture as perceived by a human watching the picture. This level is the measure of immunity of the EUT at the test frequency concerned.

4.1.3 Measurement to a limit

The actual measurement of the immunity may not be required, i.e., when it is sufficient to know whether the EUT meets a limit or not. The unwanted signal, instead of being adjusted at each test frequency, is kept at the level of the limit and its frequency swept through the test range. The EUT is considered to meet the limit if no degradation, whether objective or subjective, is observed at any time. This procedure is called a "go/no-go" test.

4.2 Immunity degradation criteria

To establish reasonable immunity criteria will require defining what is meant by performance degradation. One such view of the progressiveness of performance degradation may be as follows:

a) *no degradation:* equipment complies with its design specifications. This type of criterion shall be adopted for sensitive health and safety equipment, as well as services with impact on large populations of consumers. It might conceivably be used as an immunity criterion for some critical processes or equipment operation as well;

b) *noticeable degradation:* in this case, the performance has been affected by an EM disturbance. Increased noise in video and audio circuits, decreased signal-to-noise ratio in control circuits, error rates in digital systems approaching an allowable system maximum, or annoying audio or visual disturbances are examples of noticeable degradation. No operator intervention should be required to continue use of the electronic product/equipment. This degradation is generally used for mass produced products. The degradation disappears when the immunity signal is removed;

c) *serious degradation:* in this category, products will not be able to provide continuous satisfactory operation. To correct this, field engineering or customer service representatives will spend considerable time in the field trying to identify and correct the problem. This immunity level should be set so that it occurs on very rare occasions. operator intervention is required to restore specific operation of electronic product/equipment such as system lockups, resets, indiscriminate writing on floppy disk, and other altering of memory;

d) *failure/total inoperability:* this is the most serious category where the product totally fails and cannot be reset to regain operability. Eventually, mechanical damage will occur. No field repair can be accomplished. This creates a need for complete equipment replacement with an urgent redesign to increase its immunity level. Customer service could be interrupted for an indefinite time dependent on the capability of the manufacturer to produce a satisfactory replacement product.

It is the task of the product committees to determine the product degradation criteria for the above conditions.

4.3 Product specification details

In addition to specifying the detailed immunity measurement method and the means of determining the degradation of performance acceptable, the product specifications must include other relevant details as outlined below.

4.3.1 Test environment

The needs of the test environment must be considered. The physical environment needs to be specified, e.g., temperature or humidity ranges. Also the EM environment must be specified, in particular, the maximum level of ambient signals.

4.3.2 Working conditions of EUT

The working conditions of the EUT must be specified, e.g., the characteristics of the wanted input signal, the modes of operation of the EUT, etc.

4.3.3 EM threat

There are many forms of EM disturbances which may cause the EUT to malfunction. The product committee must consider whether the immunity specification should cover all eventualities, i.e., immunity from transmitted radio waves, from conduction of signals, from spikes/dips/outages/distortions on the mains, from electrostatic discharge, from lightning induced surges, etc.

For each potential threat, the mode of coupling must be evaluated so that the appropriate specialized test equipment can be specified together with the covered method of measurement. It will thus be necessary for the product committees to adapt the general measurement principles set out in this clause to their particular product.

The characteristics of the unwanted signal must be specified, e.g., amplitude, modulation, direction, polarization, etc. The frequency range of applicability of each method must be defined, e.g., the useful frequency range of the TEM cell is dependent on its width and this in turn is dependent upon the size of the EUT.

The EUT must be examined to determine whether it is particularly susceptible in any mode of operation or for a particular frequency of unwanted signal.

4.3.4 Calibration

The product specification must address calibration needs, either by referring to a basic standard or including the calibration procedure within the product or product family specification. This should include both the periodic calibration of the test equipment used and particularly the means of calibrating said parameters as the amplitude and homogeneity of the unwanted signal as it is used in direct radiation or injection methods.

4.3.5 Statistical assessment

The product specification must state the significance of the CISPR limit. In particular, it should address the question of whether the testing should conform to the 80/80 rule of Recommendation 46/1, and if so, which of the sampling methods should be used.

For immunity testing until a performance degradation occurs, compliance with a CISPR limit for immunity may be judged using a suitable sample size such that a portion of the sample may exceed the permissible limit. For immunity testing performed at the immunity limit to determine compliance, e.g. go/no-go testing, without measuring the margin of immunity, statistical techniques may not apply.

5 Method of measurement of immunity for conducted signals

The basic method is to inject the unwanted signal into a lead and increase the level until the specified level of degradation is observed or the specified immunity level is reached, whichever is first. The lead may be a signal, a control or mains lead. There are two variants of the method. Current injection is used to assess immunity to common mode (asymmetric) signals, the voltage injection method to assess immunity from differential mode (symmetric) signals. In general current injection is performed as a minimum since that mode is most vulnerable to radiated RF environments.

The general principle of the injection measurement is illustrated in figure 2. The effects of interference signals induced into a lead of an equipment in an actual situation are simulated by the injection of an unwanted signal through a suitable coupling unit.

In the case of current injection for unshielded leads, the unwanted current is injected in common mode into the conductors. In the case of coaxial or shielded cables the unwanted current is injected into the outer conductor or the shield of the cable also in common mode (see figure 2). The current flows through the EUT returning to the generator through the ground capacitance in parallel with the load impedances of the other terminals provided by coupling units. Note that in some cases a portion of the common mode signal is converted into differential mode, thus masking the true common-mode response. This may be a combination of common mode currents which affect the RF potential differences at opposite ends of the lead and cause a degradation of the wanted signal to unwanted signal ratios.

In the case of voltage injection, the signal is applied between two wires. Note that at frequencies approaching 100 MHz or greater, conducted immunity injection by both methods is difficult due to the impedances and resonant conditions of the EUT leads and loads.

5.1 Coupling units

The coupling units contain RF chokes, capacitors, and resistive networks for the injection of unwanted signals. The impedance of the unwanted signal voltage source and the load impedances are standardized and the coupling units are designed to provide this impedance. They also permit the passage of the wanted test signal, other signals, and mains supply. Construction details and performance checks of coupling units are contained in CISPR 16-1-2.

5.2 Measurement set-up

The arrangement used for conducted immunity measurements must be adequately specified to ensure accuracy and repeatability. Particular items to specify include:

a) height of EUT above a specified ground plane;

b) disposition of excess signal and power leads;

c) length of leads connecting coupling unit to signal and power leads;

d) control of lay-out of all components used, that is EUT, its leads, coupling unit, ground plane, interconnect leads, signal source, etc.;

e) quality of leads, that is, shield connections, transfer impedance, etc.

More details on such specifications follow for the case of measuring the immunity of TV receivers, as an example.

The TV receiver is placed 100 mm above a metallic ground plane of dimensions 2 m by 1 m. The coupling units are inserted into the various leads, respectively. The leads linking the coupling units to the EUT shall be as short as possible, in particular the lead to the antenna input of the EUT shall be not longer than 300 mm.

The mains lead shall be 300 mm long. If longer, it shall be bundled to a length of 300 mm. The mains lead shall be fixed in a well-defined lay-out which shall be recorded in the test report. The distance between the leads and the ground plane shall be not less than 30 mm.

The maximum number of coupling units used in a test shall be six. In the case of EUTs with more than six terminals, coupling units shall be used for at least one of each type of terminals, if present.

NOTE Product committees should include such details in the product specification.

5.3 Method of measurement of input immunity

The unwanted signal is applied to the input terminals of EUTs that normally receive radio-frequency signals in that manner. This unwanted signal is mixed with the desired signal. The following subclauses highlight such tests as may apply to sound and television receivers, as examples. Also, see CISPR 13.

5.3.1 Measurement of sound receivers

For these measurements the wanted and the unwanted signal frequencies shall be specified in terms of accuracy, e.g., ± 1 kHz.

The measuring set-up is shown in figure 3. The unwanted signal generator (1) and the wanted signal generator (2) are interconnected by means of the coupling network (6). To avoid mutual interference between the two generators, the coupling loss can be increased with the attenuators (7). The output of the coupling network, the source impedance of which shall be specified, shall be matched to the input terminal of the EUT by the network (8). The audio output is measured as specified.

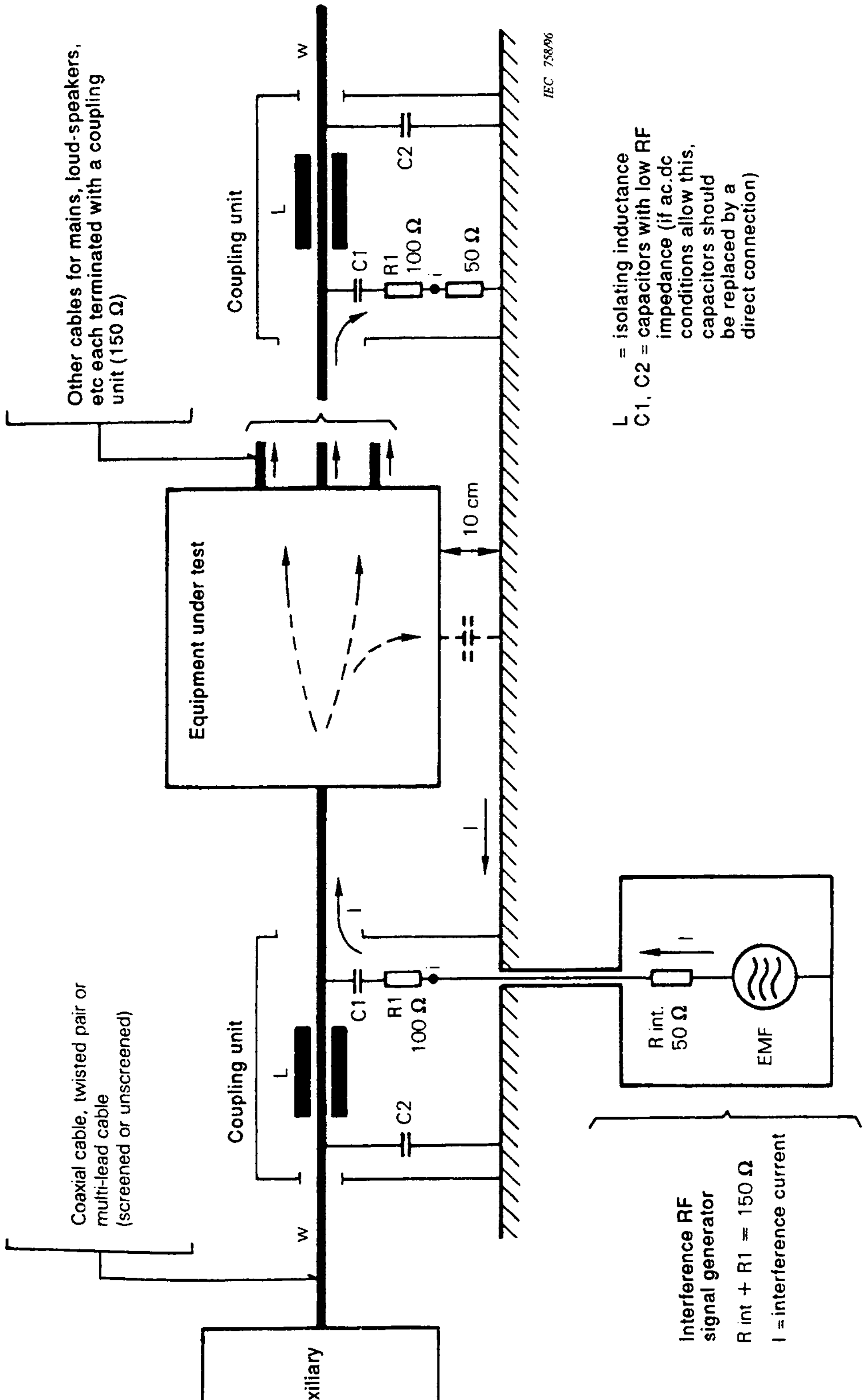
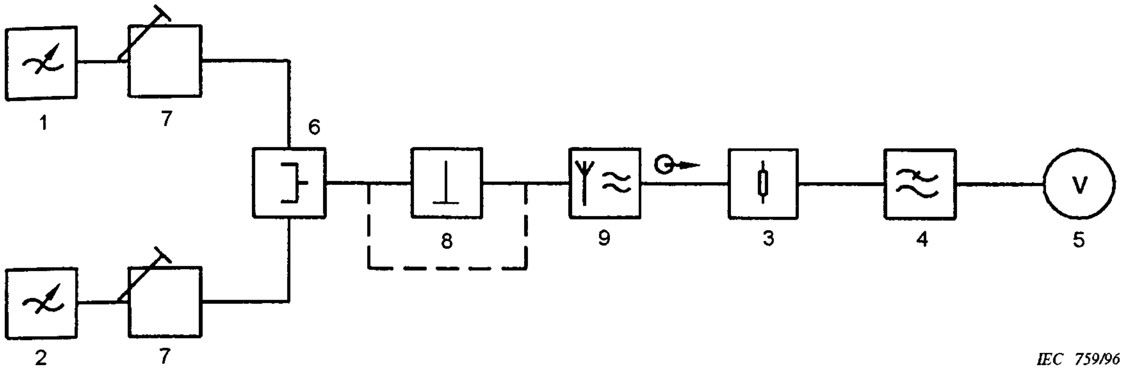


Figure 2 – General principle of the current-injection method



1 Unwanted signal generator G1
2 Wanted signal generator G2
3 Load resistor RL
4 Low-pass filter (see annex B)
5 Audio-frequency voltmeter (with weighting network according to CCIR Recommendation 468)
6 Coupling network
7 Attenuators
8 Matching and/or balancing network
9 Equipment under test (EUT)

Figure 3 – Measuring set-up for input immunity measurement of sound broadcast receivers

5.3.2 Measurement of television receivers

The measuring set-up is shown in figure 4. The principle of operation is similar to the measuring set-up of figure 3 and the remarks in 5.3.1 apply. The low-pass filter (10) is added to prevent influence of the measuring results by harmonics of the unwanted signal generators.

6 Method of measurement of immunity to radiated electric field interference

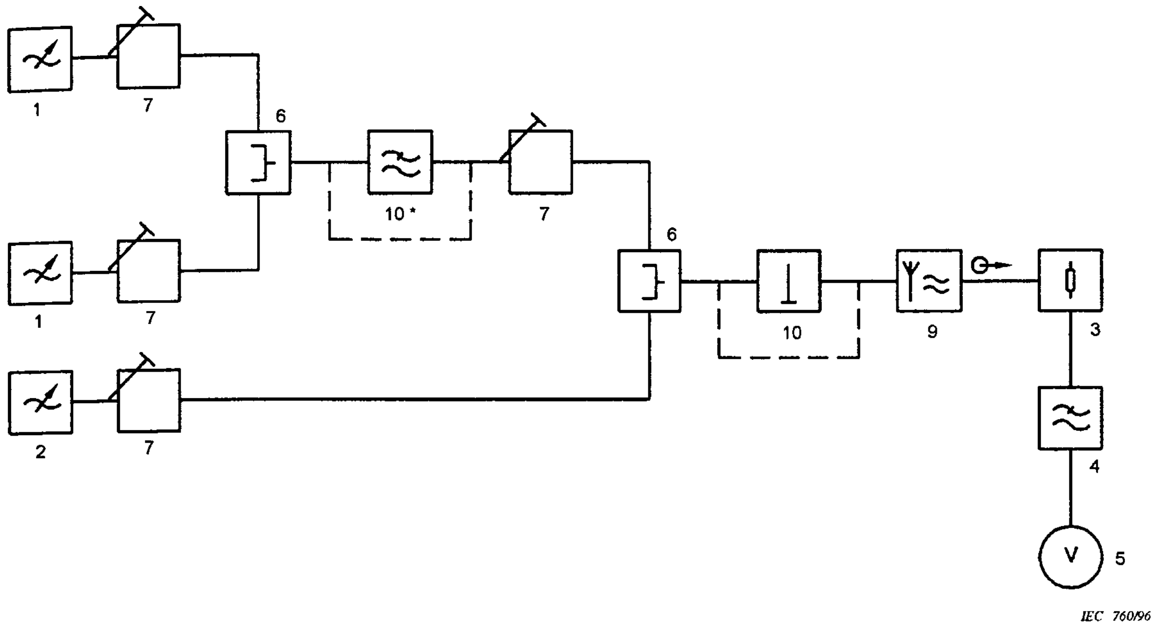
The following clauses delineate various methods of measurement of immunity to radiated electric field interference.

6.1 Measurements using the TEM mode

A homogeneous, electromagnetic wave under the free space conditions can be simulated by a guided wave of the TEM (transverse electromagnetic) mode travelling between two flat parallel conducting surfaces. In this case the electric field component is perpendicular, and the magnetic field component parallel, to the conductors. TEM devices may be of the open stripline or the closed construction, e.g. TEM or GTEM device. Details of the TEM and stripline devices are given in CISPR 16-1-2. The description of the GTEM device is under consideration.

6.1.1 Measurement set-up using the open stripline

The open stripline consists of two parallel plates sufficiently spaced apart to accommodate twice the electrical height of an EUT. The metallic structure of the EUT in the vertical plane constitutes the electrical height of the EUT. EUTs whose electrical height is greater than half the parallel plate separation may load the stripline and introduce a significant effect on the applied electric field strength. It should be noted that above the cut-off frequency of the stripline, both perpendicular and horizontal electric field strength components are present.



1 Unwanted signal generators G1
2 Wanted signal generators G2
3 Load resistor RL
4 Low-pass filter
5 Audio-frequency voltmeter (with weighting network according to CCIR Recommendation 468)
6 Coupling networks
7 Attenuators
8 Matching and/or balancing network
9 Equipment under test (EUT)
10 Low-pass filter*

* To prevent influence of the measuring results by harmonics of the unwanted signal frequency

Figure 4 – Measuring set-up for input immunity measurement of television broadcast receivers (see 5.3.2)

For the EUTs that meet the above height restriction and for testing generally under 150 MHz, the following arrangement and stripline distances are recommended:

- the base of the stripline shall be placed on non-metallic supports at least 0,8 m from the floor, and the top conductor plate shall be no closer than 0,8 m from the ceiling;
- when used in a room, the stripline shall be spaced at least 0,8 m from its open longitudinal sides to walls or other objects. When used inside a screened room, RF, absorbing material shall be placed in the space between the sides of the stripline and the walls of the screened room. Figure 5 shows the basic arrangements;
- the EUT is placed on a non-metallic support, 100 mm high, in the centre of the stripline (see figure 6);
- connecting leads to the EUT are inserted through holes in the base conductor plate of the stripline. The lengths of the leads inside the stripline shall be as short as possible and completely surrounded by ferrite rings to attenuate induced currents. The transfer impedance of coaxial cables used shall be not higher than 50 mΩ /m at 30 MHz;
- any balanced-to-unbalanced transformer used shall be connected to the EUT with leads as short as possible;
- terminals of the EUT not used during the measurement shall be terminated with shielded resistors matching the nominal terminal impedance.

If an EUT requires another apparatus in order to function properly that additional apparatus shall be considered as part of the measuring equipment and precautions shall be taken to ensure that the additional apparatus is not exposed to the unwanted signal. These precautions may include additional grounding of coaxial shields, shielding, and inserting of an RF filter on, or the application of ferrite rings to, the connecting cables.

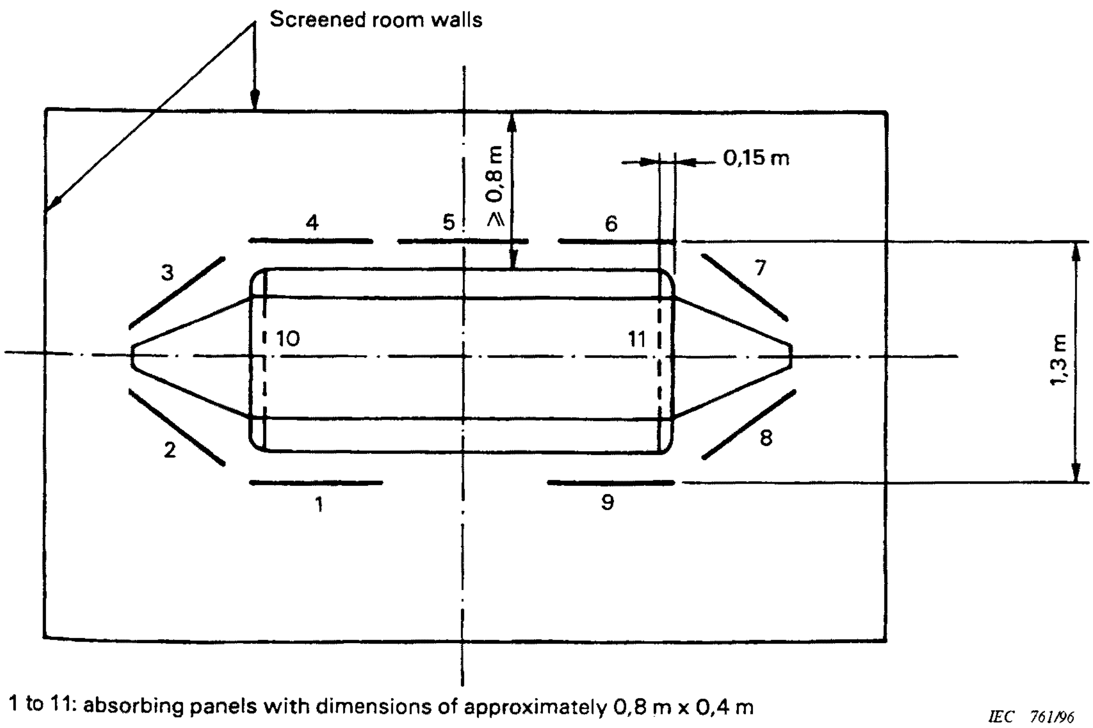


Figure 5 – Example of the arrangement of an open stripline TEM device in combination with absorbing panels inside a screened room with dimensions 3 m × 3,5 m

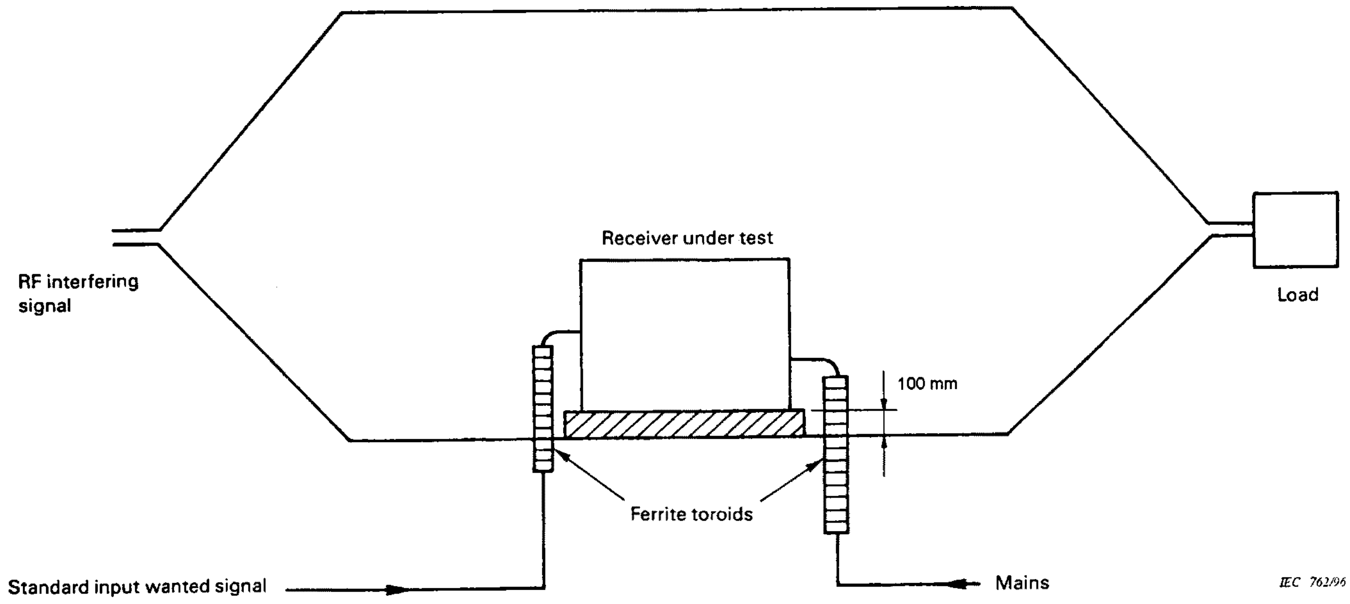


Figure 6 – Measuring set-up for the immunity of broadcast receivers to ambient fields in the frequency range of 0,15 MHz – 150 MHz

6.1.1.1 Measurement circuit for receivers

Figure 7 shows the circuit used for measuring the immunity of sound and broadcast receivers. This is an example of the use of the stripline. The wanted test signal is supplied by generator G2 and is connected through a matching network to the input of the EUT.

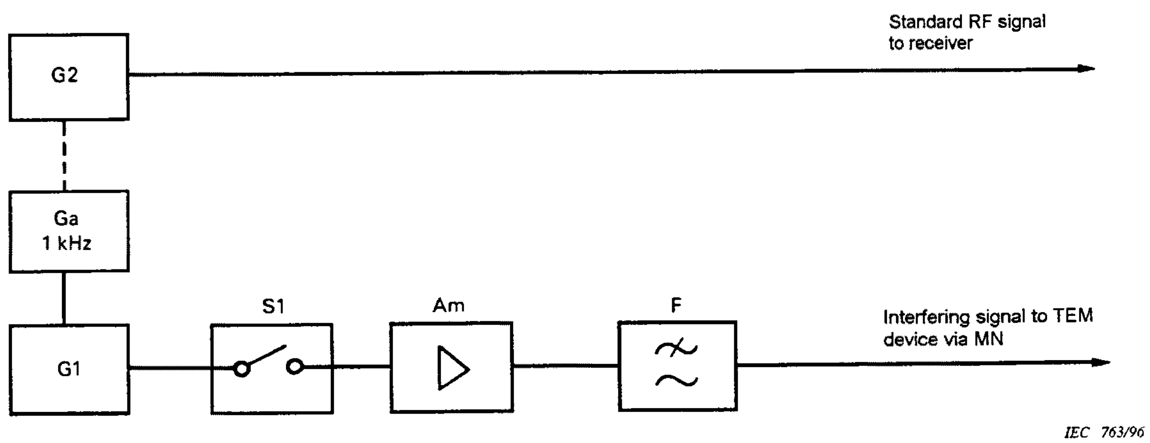


Figure 7 – Measuring circuit for the immunity of sound broadcast receivers to ambient fields

The unwanted signal is supplied by generator G1 and is connected through switch S1, wide-band amplifier Am, and low-pass filter F to a matching network MN of the stripline. The wide-band amplifier Am may be required to provide the necessary field strength. The stripline is loaded with a terminating impedance.

Care shall be taken with respect to the harmonic level of the RF output of the generator G1 and in particular the output of the wide-band amplifier Am. Harmonics may influence the measurement if they coincide with other responses of the EUT. For the case where the EUT is a TV receiver, such responses from a harmonic may be at the tuned channel or the i.f. channel of the EUT. In some cases provisions shall be made to reduce the harmonic level adequately by inserting a suitable low-pass filter F that can handle the input power from the Am. Specific checks of the suitability of these filters should be made.

The audio output power levels shall be measured as specified in the product requirements.

6.1.2 Measurement set-up using a closed TEM device

(Under consideration)

6.1.2.1 Measurement circuit

(Under consideration)

6.2 Measurement using absorber-lined shielded rooms

6.2.1 Introduction

Absorber-lined shielded rooms are comprised of a standard six-sided shielded room which has some form of RF-absorbent material applied to the four walls and ceiling. Generally, the shielded room floor is untreated and acts as the reference ground plane for measurements. For field uniformity, the floor of the room may also require the addition of absorber material. The absorber material is generally comprised of carbon-impregnated foam. Other material includes ferrite tiles or combinations of ferrite tiles and carbon-impregnated foam. Both materials dissipate the undesirable energy impinging on its surface in the form of heat. For high power immunity levels, due concern for exceeding the heat dissipation rating of the absorbing material should be given. Special fire-retardant treatments are available for the material.

6.2.2 Size

The size of absorber-lined shielded rooms depends on several factors:

a) test area needed for the EUT system;

b) volume necessary to accommodate the transmitting antenna and its required height(s) above the ground plane;

c) size of the absorber material;

d) separation between the antenna and EUT;

e) separation between the EUT and antenna from the closest absorbing material;

f) the dimensional sizes of the chamber required to give the required accuracy and uniformity of immunity field in the test area.

The size of the absorber-lining material needed is a function of the amount of suppression required of the undesired reflections. Such material which is generally pyramidal in shape for carbon foam is effective when the height of the material is a significant fraction of a wavelength. When this fraction is realized, the absorbing material can attenuate the reflected energy by 20 dB or more. The attenuation values increase considerably when the wavelength is less than that of the height of the pyramidal material. Conversely, the attenuation is degraded to a very low level for carbon-foam absorber material height much less than a wavelength. This latter condition is usually the case for most practical sized absorber material (1 m or less in height below 100 MHz). Use of such absorber-lined rooms is thus seriously restricted at these frequencies or lower.

The response of absorber lined chambers under 100 MHz can be improved by a suitably chosen layer of ferrite tiles and carbon-foam material. In general, the layering consists of ferrites directly mounted on the shielded room walls and ceiling (and perhaps flooring), a layer of dielectric material, the carbon-foam material, and in case of floor applications, an inert fill between the pyramids and a mechanically strong, load-bearing, non-conductive "walk-on" material. The ferrite yields additional reflection reduction below 100 MHz (if properly selected). It should be noted that such ferrites are non-linear suppression materials. The impact on the absorber room reflective properties as a function of frequency should be characterized before using such material, especially above 1 GHz.

6.2.3 Transmitting antenna

There are many varieties of transmitting antennas that can be used to reproduce the desired immunity field inside an absorber-lined shielded room. The most critical parameters for such antennas are the ability to dissipate high powers (up to 1 kW) and to have a beamwidth sufficiently wide to illuminate the EUT test area. If polarization information is necessary, linearly polarized antennas should be used. Typical antennas include high power biconical, log periodic arrays and ridged rectangular horns. These antennas should stand well clear of any absorber material. At least a 1 m clearance is suggested.

6.2.4 Signal generation

No special signal generator requirements other than adequate suppression of signal generator and power amplifier harmonic and spurious outputs are needed when immunity tests are performed inside an absorber-lined shielded room. The signal sources should be capable of producing both CW and modulated RF carrier levels compatible with the input requirements of the power amplifier used to feed the transmit antenna. Since the EUT may respond to several frequencies over a large bandwidth, it is important that the combination of the signal generator and power amplifier adequately suppress harmonic and spurious outputs. The suppression should be 30 dB or more compared to the desired frequency output and to the immunity limit at these harmonics. A high-power low-pass filter which tracks the output signal may have to be inserted between the amplifier output and the transmitting antenna input.

6.2.5 Calibration of generated electric field

The purpose of field calibration is to ensure that the uniformity of the field over the test sample is sufficient to ensure the validity of the tests results.

This standard uses the concept of a "uniform area" which is a hypothetical vertical plane of the field in which variations are acceptably small. This uniform area is 1,5 m × 1,5 m, unless the EUT and its leads can be fully illuminated within a smaller surface. In the test arrangement, the EUT will have its front face coincident with this plane.

Because it is impossible to establish a uniform field close to an earth reference plane, the calibrated area is established at a height no closer than 0,8 m above the earth reference plane and where possible the EUT is located at this height.

In order to establish the severity of the test for EUTs and wires which must be tested close to the earth reference plane or which have larger sides than 1,5 m × 1,5 m, the intensity of the field is also recorded at 0,4 m height and for the full width and height of the EUT, and reported in the test report.

The antennas and cables which have been used to establish the calibrated field shall be used for the testing. Since the same antennas and cables are used, the cable losses and antenna factors of the field generating antennas are not relevant.

The exact position of the generating antenna shall be recorded. Since even small displacements will significantly affect the field, the identical placement must be used for testing.

NOTE The area of the uniform field should be established at 3 V/m by an unmodulated RF signal. Use of an unmodulated signal assures proper indication of any field intensity measuring device.

6.2.6 Performance monitors

Based on the test plan, various sensors should be attached to the EUT to be able to record an analogue or digital signal, which will indicate performance degradation. These sensors and the leads extending outside the absorber-lined shielded room should not affect the performance or immunity of the EUT nor become uncalibrated by the applied immunity field or the presence of the absorber lining. In some cases, the leads from the EUT to the EUT support equipment outside the absorber-lined shielded room can be monitored for performance degradation. The degradation monitors in this case do not have to be immune to the radiated RF energy. They should, however, be immune to any conducted RF currents on the leads outside the room. If visual performance degradation is required, a suitable clear window panel on the shielded room wall or closed circuit television system can be used. The panel area should be converted with an integral shielding material, i.e. wire mesh embedded in glass or conductive transparent material applied to the glass surface. The TV camera should be located embedded inside adjacent pyramidal tips of the carbon-foam material in a position within the room that does not intercept a major reflected EUT signal. Audio degradation can be measured via acoustic couplers or by monitoring the recovered audio modulation of the amplitude modulated RF immunity signal carrier.

6.2.7 Immunity measurement set-up

6.2.7.1 The EUT is set in the centre of the test zone of the absorber-lined shielded room. A uniform test field for small products, that is, the EUT linear dimensions are less than a wavelength, is obtained when the antenna separation is greater than a wavelength away. The field becomes complex for separations closer than a wavelength. For larger products, i.e., where the EUT dimensions are greater than a wavelength, the antenna should be separated by a distance equal to the largest linear dimension of the EUT in metres squared divided by the wavelength of the immunity signal. If measurements are made at closer separations, the receive antenna will be in the complex near field zone. This complexity must be accounted for in such tests to assure repeatability and the prediction of the far field from such near field data.

6.2.7.2 Performance monitors are attached to the EUT as required in the test plan. Field strength sensors, if used, should be placed to monitor or provide field levelling only if the field that is being recreated was so measured at the actual product location when used by a customer. All connections should not be affected by the field or absorber material nor change the performance of the EUT.

6.2.7.3 The transmitting antenna should be mounted on an antenna positioner capable of varying the polarization, height and location of the antenna with respect to the ground plane and EUT. Narrow beamwidth antennas should be kept pointed at the EUT as they are raised and lowered.

6.2.7.4 Provisions should be made to monitor and record the various performance degradations specified in the test plan. It is strongly suggested where possible that subjective visual or aural monitoring by a test operator be replaced with objective analogue or digital voltage or current EUT response. This electrical monitoring technique minimizes tester errors that result due to the tedious and lengthy test cycle nature of immunity measurements.

6.2.8 Immunity test procedure

The test procedures for immunity measurements inside absorber-lined shielded rooms are generally the same as those inside a regular shielded room. Since the interaction of all the reflected signals normally present in an absorber-lined shielded room are much less, absorber-lined room measurements are more accurate and repeatable. In both cases, the test personnel and test instrumentation (amplifier, signal source, etc.) should be located outside the room.

The general test procedure includes the following:

a) establish the calibrated disturbance field strength, polarization and modulation (if any is required);
b) configure and operate the EUT as typically used and orient the EUT to maximize its immunity response;
c) vary the transmitted signal limit at each frequency to measure the level at which degradation occurs or at the specified immunity level, whichever is lower;
d) scan the frequency range contained in the test plan to complete the EUT immunity profile or to determine go/no-go compliance;
e) record the performance degradation and the associated field strength levels as a function of frequency and the other test parameters.

6.3 Measurements using an open area test site (OATS)

6.3.1 Introduction

Radiated immunity field strength levels are by their very nature significantly higher than radiated emission levels normally regulated by national governments. Typical test levels for much equipment are in excess of 1 V/m. For some EUT systems and large stand-alone electronic equipment, the need to illuminate the entire EUT requires high power, an efficient and wide beamwidth transmitting antenna, and a large test area. The power and antenna requirements are generally independent of the type of test facility used. In some cases the large EUT is not completely functional until all its parts are assembled on site at the user's premises or at a test site that is quite large. One such test site is the same open area test site used for radiated emission measurements. These sites are useful over the full frequency range and have particular applicability above 30 MHz subject to the severe restrictions stated in 6.3.3.

6.3.2 Measurement site requirements

The open area immunity test site (OAITS) that meets the same requirements for the open area test site (OATS) specified in clause 5 of CISPR 16-1-4 are physically suitable for immunity tests. Other sites may be used as long as the electric field strength in the volume occupied by the EUT does not vary by more than the specified tolerance. This may require that the transmitting antenna be located on an antenna positioner to change the antenna height and in some cases, polarization, above the ground plane and antenna location. In changing the antenna height, narrow beam-width antennas must be kept pointed towards the EUT. Height change would be used to adjust the addition of the direct signal and then reflected from the ground screen so that a specified uniform field is found in the EUT volume as frequency varies. These requirements need only hold for the frequency range specified in the test plan. Absorber material may be required on the ground plane to meet the field uniformity requirement.

6.3.3 Interference to radio services

The potential for causing interference to licensed radio-frequency services in or near the OAITS is generally high due to the very magnitude of the immunity signal. Extreme care should be taken to ensure that the generation of the test field does not adversely affect such RF services, especially in the various safety bands. Fields no higher than needed to measure to the specification limit or to record an EUT performance degradation below that limit should be generated. If generated, they should be applied for very brief time intervals.

There may be certain frequency bands where the interference potential is significantly reduced. For example, ISM band frequencies are likely to be unaffected by such measurements. In some administrations it may be required to secure an experimental radio license from the national authority. The license would detail specific frequencies, time of operation, and length of operation for the immunity RF field strength transmission. Generally, experimental licenses for frequencies used for public radio emergency services, commercial broadcast, government channels, standard time and frequency broadcasts, etc. are not granted. Use of ISM frequencies and other industrial use frequencies are generally more likely to be approved. Note, however, that these approval frequencies may be so spaced apart that the true immunity response will not be completely described.

Under far-fielded conditions the ambient interfacing field E is given by:

$$E = 2 \times 7 \frac{[PG]^{1/2}}{d} = 14 \frac{U}{d}\left[\frac{G}{R}\right]^{1/2}$$

where

U is the input voltage at the tuned radiating antenna with resistance R;

d is the distance between antenna and the location where a sensitive radio receptor may be located;

G is the gain of the antenna with respect to a half-wave dipole.

The factor 2, with an accuracy of 1,5 dB, implies the effect of the total reflection at the ground plane if the height of the transmit antenna is adjusted for maximum field strength. In the case of a vertically polarized transmit antenna, the effective field resulting from the direct and from the reflected field may not be a vertically linearly polarized field.

6.3.4 Measurement procedures

6.3.4.1 General

Basically, the immunity measurement procedures are the same as those for measurements made using any enclosed test site such as a TEM cell or shielded (absorber-lined or not) room. In the case of the TEM cell the signal is applied between the centre conductor and the outer shell; in the OAITS and other more common shielded enclosures, the immunity signal is fed to a transmitting antenna.

6.3.5 Measurement set-up using the open area test site

6.3.5.1 General

The power required to establish an immunity field strength is not small. Hence the closer the EUT is to the antenna, the less power required. Most OAITS measurements are performed using EUT/antenna separation distances less than 3 m. For large EUTs, this distance must be increased so that the antenna can illuminate the entire EUT. Power amplifier expense and availability over the frequency range up to 1 000 MHz usually limit large system testing. Component or partial EUT testing is substituted in some cases and judgements made as to the overall large system EUT immunity.